

UNCLASSIFIED

AD 281 862

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

**Best
Available
Copy**

281 862

62-4-5

PROJECT NO. RSSH-31003

DATE: 21 JUN 1962

43-62

281862

CATALOGED BY ASTIA

AS AD NO.

NAVAL AIR TEST CENTER

Patuxent River, Maryland

Report

WEPTASK RA1200001/201 1/F012-15-002
PROBLEM ASSIGNMENT RSSH-31003

OPTIMUM WIND-OVER-DECK FOR SHIPBOARD
RECOVERY OPERATIONS WITH CARRIER BASED
AIRPLANES

REPORT NO. 2
FINAL REPORT

Released to ASTIA by ~~NAVAL~~ NAVAL WEAPONS
Bureau of
without restriction



ASTIA

AUG 13 1962

TISIA

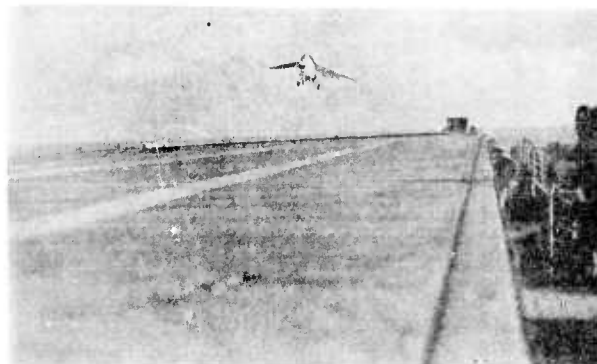
FLIGHT TEST DIVISION

RA1200001
(RSSH-31003)
FT2222-176

NAVAL AIR TEST CENTER
U. S. NAVAL AIR STATION
Patuxent River, Maryland

21 JUN 1962

WEPTASK RA1200001/201 1/F012-15-002, Problem Assignment
RSSH-31003, Optimum Wind-Over-Deck for Shipboard Recovery
Operations with Carrier Based Airplanes; Report No. 2,
Final Report



ABSTRACT

1. Airflow disturbance aft of the ramp and in the landing area is one of the most significant adverse influences on the pilot's ability to make a precise carrier final approach and landing, and is primarily affected by the Wind-Over-Deck (WOD). Tests conducted on board USS MIDWAY (CVA-41), USS RANGER (CVA-61), USS CORAL SEA (CVA-43) and USS SARATOGA (CVA-60) determined that, from the pilot's viewpoint, a WOD of 25 kt for jet and 15 kt for propeller airplanes is optimum. Conclusions are drawn concerning required glide slope angles and the undesirable demands imposed on pilots by variations in carrier landing conditions.
2. The determination of an optimum WOD must be predicated upon operational feasibility as well as pilot considerations. A 25 kt WOD, in comparison with a 35 kt WOD, accrues the following advantages for jet airplanes: Less demanding on the pilot; reduction in landing gear loads; improved approach airspeed control; less deviation in alignment; and increased jet recovery flexibility. The increased closure rate of a reduced WOD results in the following disadvantages: Earlier wave-off initiation; slightly degraded landing dispersion; and increased bolter rate. Based on arresting gear and/or airplane limits, fleet capability for utilizing a reduced WOD is determined.
3. It is concluded that any operationally feasible reduction in WOD that is standardized as optimum for individual carriers, and is as near as practicable to 25 kt for jet and 15 kt for propeller airplanes, will improve safety of recovery operations.

RA1200001
(RSSH-31003)
FT2222- 176

TABLE OF CONTENTS

	<u>Page No.</u>
Introduction and Purpose.....	1
Description of Test Airplanes.....	2
Record of Tests.....	2
Scope and Methods of Tests.....	3
Results and Discussion	
Airflow Disturbance.....	4
Variations in Carrier Landing Conditions.....	6
Analysis of Airplane Landing Parameters.....	7
Operational Considerations.....	9
Conclusions.....	13
Recommendations.....	14
Enclosures (12)	

RA1200001
(RSSH-31003)
FT2222- 176

FINAL REPORT ON
WEPTASK RA1200001/201 1/F012-15-002
PROBLEM ASSIGNMENT RSSH-31003
OPTIMUM WIND-OVER-DECK FOR SHIPBOARD RECOVERY
OPERATIONS WITH CARRIER BASED AIRPLANES

21 JUN 1962

PREPARED BY:

R. M. DECKER
Project Engineer

LCDR N. A. CASTRUCCIO, USN
Project Pilot

REVIEWED BY:

CDR G. W. ELLIS, USN
Head, Carrier Suitability
Branch

APPROVED BY:

B. V. STUBER
Chief Project Engineer

F. G. EDWARDS
Captain, U. S. Navy
Director, Flight Test

NAVAL AIR TEST CENTER
U. S. NAVAL AIR STATION
Patuxent River, Maryland

RA1200001
(RSSH-31003)
FT2222- 176

21 JUN 1962

From: Commander, Naval Air Test Center
To: Chief, Bureau of Naval Weapons

Subj: WEPTASK RA1200001/201 1/F012-15-002, Problem
Assignment RSSH-31003, Optimum Wind-Over-Deck
for Shipboard Recovery Operations with Carrier
Based Airplanes; Report No. 2, Final Report

Ref: (a) BuWeps ltr RSSH-3121-DDF:mja of 28 May 1960
(b) NATC spdltr PTR RSSH-31003 ser FT2222-40 of 1 Feb 1961
(c) NATC spdltr PTR RSSH-31003 ser FT2222-276 of 8 Aug 1961
(d) NATC spdltr RA1200001 (RSSH-31003) ser FT2222-348
of 9 Oct 1961
(e) Spec MIL-A-8629 (Aer) of 28 Aug 1953

Encl: (1) Data Recorded and Associated Accuracies of Data
— (2) Arrested Landing Tabulated Data, USS GORAL SEA
(CVA-43)
(3) Summary of Optimum WOD Landings
(4) Summary of Airplane Landing Parameter Analysis
(5) Minimum WOD Requirements for Most Critical Jet and
Propeller Airplanes
(6) Annual Percentage Frequency of Surface Wind in
Carrier Operating Areas
(7) Frequency Distribution of Model A4D Airplane Landing
Parameters
(8) Frequency Distribution of Model F8U Airplane Landing
Parameters
(9) Comparison of Percent Ultimate Sinking Speed/Roll
Angle Envelope
(10) Determination of Equations Utilized in the
Statistical Analysis of Airplane Landing Parameters
(11) Abbreviations and Symbols
(12) Bibliography of Selected Reports Pertinent to
"Burple" and WOD Variation

INTRODUCTION AND PURPOSE

1. Reference (a) established Problem Assignment RSSH-31003 with a "B" priority to determine if an optimum wind-over-deck (WOD) exists for the recovery of the various model airplanes currently assigned to the Fleet. Specific requirements were:

RA1200001
(RSSH-31003)
FT2222-176

a. To determine whether an optimum WOD exists for particular groupings of models, such as by gross weight, wing loading or approach speed.

b. To evaluate the significance of variation from an optimum WOD, if established, on landing parameters such as approach speed, sinking speed, off-center distance and bolter rate.

2. Results of qualitative tests conducted on board USS MIDWAY (CVA-41), USS CORAL SEA (CVA-43) and USS SARATOGA (CVA-60) are reported in references (b) through (d), respectively.

DESCRIPTION OF TEST AIRPLANES

3. Model F8U-1/2, F4D-1, A4D-2, A3D-2P and TF-1 airplanes were used in the prosecution of the problem assignment. All were representative of production airplanes except models F8U-1 BuNo 143749 and A4D-2 BuNo 142089, which contained test instrumentation required for other projects, but not used during these tests.

RECORD OF TESTS

4. The below summary is a chronological record of tests conducted:

a. Date of project directive	28 May 1960
b. USS MIDWAY (CVA-41) Trials	12-16 Dec 1960
c. USS RANGER (CVA-61) Trials	24-27 Feb 1961
d. USS CORAL SEA (CVA-43) Trials	14-21 Jul 1961
e. USS SARATOGA (CVA-60) Trials; Flying Completed	11-21 Sep 1961
f. Data reduction of CORAL SEA tests of NATC airplanes completed	15 Dec 1961
g. CORAL SEA data analysis completed for NATC airplanes	9 Mar 1962

RA1200001
(RSSR-31003)
FT2222-176

SCOPE AND METHODS OF TESTS

5. This final report reflects the conclusions of references (b) through (d), includes qualitative test results not previously reported from trials on board USS RANGER (CVA-61), and reports the results of landing parameter analysis of both quantitative and qualitative data obtained from tests conducted on USS CORAL SEA (CVA-43).

6. Qualitative evaluation was made of day carrier approaches and landings under WOD conditions varying between 15 and 45 kt for jet and between 7 and 30 kt for propeller airplanes. Particular emphasis was placed on obtaining a large sample of pilot and landing signal officer (LSO) opinion aboard MIDWAY and RANGER, where 15 pilots flew 5 different model airplanes. Each pilot conducted two or more periods of touch-and-go landings in each model flown. One or more periods were at a high WOD and one or more at a low WOD value. The time interval between two periods for an individual pilot was held to a minimum.

7. Night qualitative evaluation was conducted on board SARATOGA and reported in reference (d). Tests consisted of two pilots' participation in one day period each, followed by two night periods each during one day's operation. The models F8U-2 and A4D-2 airplanes were utilized. WOD for the day and first night periods was 25 kt, while 35 kt was maintained for the second night period. Comparative results were thus determined between day and night landings for two WOD values.

8. Optimum WOD tests were conducted aboard CORAL SEA with three model A4D and two model F8U airplanes in order to obtain a representative sample of quantitative data (307 landings) for WOD values of 25 and 35 kt. Each pilot/airplane combination was maintained throughout the tests in order to provide a statistical comparison between a 25 kt WOD/ $3\frac{1}{2}^{\circ}$ glide slope and a 35 kt WOD/ 4° glide slope for the following airplane landing parameters:

- a. Approach speed.
- b. Actual and theoretical sinking speeds.
- c. Off-center distance at both the ramp and at touchdown.

RA1200001
(RSSH-31003)
FT2222-176

d. Actual and theoretical touchdown distances from the ramp.

e. Main gear to ramp clearance.

f. Roll angle at touchdown.

All data for the above parameters were obtained from camera coverage of the landing area except airplane approach speed, which was obtained from the ship's AN/SPN-12 radar. The MK VI Mod 0 Fresnel Lens Optical Landing System (FLOLS) was adjusted to maintain approximately the same hook touchdown distance from the ramp for both a $3\frac{1}{2}^\circ$ and 4° glide slope setting.

9. Qualitative data were obtained from debriefings, flight reports and questionnaires completed by pilots and LSO's. Quantitative data recorded, with source and associated accuracies, are presented in enclosure (1). Arrested landing data obtained for test airplanes aboard CORAL SEA are contained in enclosure (2). As reported in reference (c), quantitative data were additionally recorded for approximately 890 fleet carrier qualification (CarQual) landings of A3D, A4D, F3H and FJ-4B airplanes, utilizing a WOD of 25 to 40 kt. These CarQual data do not constitute a part of this report and will be forwarded separately to BuWeps upon completion of analysis of the airplane landing parameters.

10. Enclosure (3) contains a tabulated summary of landings made on each carrier by test airplanes. Enclosure (10) presents the methods used for determining glide slope presentation at touchdown with respect to the angle deck, the theoretical sinking speed and the theoretical touchdown distance. Abbreviations and symbols contained herein are listed in enclosure (11).

RESULTS AND DISCUSSION

Airflow Disturbance

11. Airflow disturbance aft of the ramp and in the landing area is one of the most significant adverse influences on the pilot's ability to make a precise final approach and landing. Airflow disturbance aft of the ramp, or "burbble", may be generally described as a downdraft of varying intensity immediately aft of the ramp, followed by a resultant updraft of varying and shifting location in the vicinity of 1000 ft

astern. "Burbles" and airflow disturbance in the landing area are caused by the relationship of fixed and variable factors, some of which are sufficiently within the operational commander's control to minimize their adverse effects. Ship design characteristics vary considerably among classes and exert a significant influence on the air mass through which the pilot must fly. The magnitude and direction of the WOD is the most significant variable influencing airflow disturbances. It has been determined that for a given magnitude of WOD that the airflow in the landing area is steadiest when the relative wind direction is parallel to the angled deck centerline. Starboard recovery crosswinds are accompanied by relative wind velocities in the landing area considerably lower than those recorded by superstructure mounted anemometers. Airflow conditions in the landing area improve when the magnitude of the WOD is reduced. The "burbles" aft of the ramp become stronger when: the magnitude of WOD increases; the angle between the relative wind and the angled deck centerline increases; the natural wind component increases for a given WOD. Other variable factors influencing airflow disturbance include flight deck spot, aircraft exhaust or prop wash over the deck and natural turbulence. Enclosure (12) is a compilation of selected reports pertaining to WOD surveys and tests, which directly relate to airflow disturbances.

12. Glide slope and lateral corrections required by the pilot increase with increased WOD. Upon first entering the "burbles" with high WOD (above 35 kt) airplanes generally experience a significant upward displacement from the glide slope followed by a downward displacement near the carrier ramp. The downdraft effect is also a function of the airplane's position on the glide slope at the time of transiting the downdraft; a low position results in a deeper penetration of the "burbles" and maximum downdraft effect. All pilots reported that regardless of the model airplane being flown, the tendency for the airplane to go low on the glide slope increased considerably as WOD increased above 25 kt and 15 kt for jet and propeller airplanes, respectively. The pilot control requirement is greater for low approach airspeed and lower wing loading airplanes. To counteract the tendency of the airplane to go low during high values of WOD, all pilots anticipated the effects of downdraft by adding power approximately 400 ft from the ramp. The amount of power addition varied among airplanes of different models. Generally, an increase of about 4-6% RPM was sufficient to maintain glide slope for jet airplanes at WOD values in excess of 25 kt.

Variations in Carrier Landing Conditions

13. Variations in WOD require pilots to compensate for differences in the airflow pattern aft of the ship and in the landing area (paragraphs 11 & 12), alter the 180° position and change the power setting utilized on the glide path for a fixed Optical Landing System (OLS) glide slope. It is highly desirable that these variables be minimized, and pilots be made aware of any significant deviation from expected landing conditions.

14. The turn off the 180° position was delayed 8 to 10 sec at low WOD (20-25 kt) in comparison to approaches with 30-35 kt WOD to allow 25-30 sec in a one-mile final approach.

15. Airplane approach power settings which are optimum and to which the pilots have become accustomed should be maintained relatively constant. This is synonymous to maintaining the glide path of the airplane relative to the air mass (airplane rate of descent) relatively constant. By maintaining the same approach power settings at low WOD values, trim requirements and wave-off (WO) capability remain the same, except that the WO maneuver should be initiated earlier because of increased closure rate. Shipboard airplane power settings will remain approximately the same as those utilized for field carrier landing practice (FCLP) if OLS glide slope angles are adjusted in the following manner:

<u>Approach Speed - 100 kt</u>		<u>Approach Speed - 135 kt</u>	
<u>WOD, kt</u>	<u>Glide Slope Setting, deg</u>	<u>WOD, kt</u>	<u>Glide Slope Setting, deg</u>
0	3	0	3
15	$3\frac{1}{2}$	20	$3\frac{1}{2}$
25	4	35	4

For jet airplanes, a $3\frac{1}{2}^{\circ}$ glide slope is recommended for 25 kt WOD and a 4° glide slope for WOD values greater than 30 kt. There is a greater tendency for airplanes to be low at the ramp with WOD above 30 kt when using a $3\frac{1}{2}^{\circ}$ vice a 4° glide slope setting. This is attributed to a deeper penetration of the "burble" with the lower glide slope.

Analysis of Airplane Landing Parameters

16. Enclosure (4) is a summary of the analysis of the airplane landing parameters investigated aboard CORAL SEA at both WOD conditions. Quantitative data for this analysis are based upon 307 landings conducted by three model A4D and two model F8U airplanes. Enclosures (7) and (8) contain the frequency distribution of the parameters for the A4D and the F8U airplanes, respectively. Paragraphs 17 through 24, below, discuss the results of landing parameter analysis of the CORAL SEA tests. The term "deviation", as used in this report, includes at least 99 per cent of all the variates and represents 3σ (where σ is the standard deviation).

17. Sinking Speed. The use of a 25 kt WOD and $3\frac{1}{2}^\circ$ glide slope angle theoretically provides a 0.5 fps reduction in sinking speed from that resulting from a 35 kt WOD and 4° glide slope angle. The model A4D airplanes' average sinking speed data in enclosure (4) conform with theory, having a 12.0 fps average sinking speed at 25 kt WOD and a value of 12.5 fps with 35 kt WOD. The model F8U airplane, however, experienced the same average sinking speed, 14.0 fps, for both the 25 kt and 35 kt WOD values. Considering the related parameter of deviation in sinking speed, both airplanes experienced a deviation of 1 fps less with a 25 kt WOD.

Deviation in Sinking Speed

	<u>25 kt WOD</u>	<u>35 kt WOD</u>
A4D	4.5 fps	5.5 fps
F8U	5.0 fps	6.0 fps

The sinking speed data of enclosure (4) indicate there is less probability of exceeding maximum design sinking speed when using a 25 kt WOD.

18. Frequency of High Landing Gear Loads (Sinking Speed/Roll Angle Parameters). Reference (e) specifies that with a 7° roll angle the airplane ultimate sinking speed is reduced by 50%. Enclosure (9) contains a comparison of the actual sinking speed/roll angle combinations with 25 kt and 35 kt WOD. The per cent of ultimate sinking speed/roll angle envelope was determined by the method contained in enclosure (10). The

RA1200001
(RSSH-31003)
FT2222-176

average percent of ultimate of these parameters for the A4D airplanes with 25 kt WOD is 56.0% and with 35 kt WOD is 61.0%. For the F8U airplanes the average percent of ultimate is 64.5% with 25 kt WOD and 68.5% with 35 kt WOD. The deviation, in percent of ultimate, is 16.0% less with 25 kt WOD than with 35 kt WOD for the A4D, and 12.0% less with 25 kt WOD than with 35 kt WOD for the F8U. The use of a 25 kt WOD, as compared to a value of 35 kt, reduces the frequency of high landing gear loads for jet airplanes.

19. Control of Airplane Approach Speed. As indicated in enclosure (4), the deviation from desired approach speed was slightly less with a 25 kt WOD than with a 35 kt WOD for both model airplanes.

20. Control of Alignment. For both models tested, the overall tendency was to be right of the centerline under both WOD conditions. Four of the five airplanes (three A4D and one F8U) experienced less deviation in line-up at touchdown at 25 kt WOD, and the other F8U airplane experienced the same deviation for both WOD conditions (enclosure (4)).

21. Landing Dispersion. Data analysis determines that the average main gear touchdown distance from the theoretical for the A4D airplanes was approximately 50 ft short for 25 kt WOD and 40 ft short for 35 kt WOD. The A4D data also show the deviation from the theoretical touchdown distance to be larger for 25 kt WOD (100 ft) than for 35 kt WOD (85 ft). The model F8U airplane average touchdown distance was closer to the theoretical with 25 kt WOD (5 ft short) than with 35 kt WOD (15 ft short), but the deviation was the same (120 ft) for both WOD values. The use of a 25 kt WOD therefore indicates a 15 ft increase in touchdown deviation for recovery of the model A4D airplane, with the average touchdown distance from the theoretical being 10 ft further aft (at 50 ft short). For the model F8U airplane, with 25 kt WOD, although no change in deviation was experienced, the average touchdown distance was 10 ft farther forward (at 5 ft short of the theoretical).

22. Bolter Rate. The method of determining the bolter rate during touch-and-go landings is contained in enclosure (10). The three A4D airplanes had a 1.5% bolter rate with 35 kt WOD and a 3.0% bolter rate with 25 kt WOD. The two F8U airplanes' bolter rate was 7.0% with 35 kt WOD and 12.5% with 25 kt WOD. By eliminating the first period of touch-and-go

landings by each pilot, the F8U bolter rate was 11.5% with 25 kt WOD and 8.0% with 35 kt WOD, while the A4D bolter rate was 4.5% with 25 kt WOD and 1.5% with 35 kt WOD. Analyzing the bolter rate in this manner appreciably decreases the number of landings with 25 kt WOD, since two A4D airplanes and one F8U airplane utilized this WOD condition for their first period. However, both models would have experienced a higher bolter rate with 25 kt WOD than with 35 kt WOD had arrestments been made on all landings.

23. Closure Rate. For a constant approach airspeed of 135 kt, for example, a 25 kt WOD results in an approximate 10% increase in rate of closure above that for a 35 kt WOD. The resultant disadvantage of a higher closing speed on wave-off initiation has been previously discussed. The larger deviation of the model A4D airplane from the theoretical touchdown and the increased bolter rate of both the A4D and F8U airplanes are considered largely attributable to the approximately 10% higher relative closure speed associated with a 10 kt reduction in WOD.

24. Main Gear to Ramp (MG/R) Clearance. Sufficient data are not available to compare the MG/R clearance at the two WOD conditions, although it appears that this clearance was slightly higher than the theoretical for both WOD conditions. When using a $3\frac{1}{2}^{\circ}$ glide slope for a 25 kt WOD, approximately 2 ft less MG/R clearance will be afforded than for the 4° glide slope previously recommended for a 35 kt WOD. Where limited distance exists from the ramp to the No. 1 pendant, the reduced glide slope angle occasioned by a lower WOD presents a disadvantage of the 25 kt WOD, particularly for deck motion in pitch.

Operational Considerations

25. Frequency of Prevailing Wind Values. A WOD that can be predictively utilized operationally must be considered with respect to the prevailing surface winds over the oceans. Tabulated in enclosure (6) are the average annual surface wind percentage frequencies in various carrier operating areas. The surface wind is 16 kt or less in the tabulated operating areas 65% of the time. A WOD of 25 kt can therefore be more consistently obtained than one of 35 kt. Prevailing surface winds, required speed for steerage and carrier capability to make rapid changes in speed decrease the

RA1200001
(RSSH-31003)
FT2222- 176

possibility of using 15 kt WOD for propeller operations, since 57% of the time the surface winds are greater than 10 kt in the operating areas. It is indicated that from a standpoint of prevailing surface winds, the use of a 25 kt WOD would greatly increase flexibility of jet carrier operations, and that although desirable for predominantly propeller operations, a 15 kt WOD will be available less often.

26. Increased Engaging Speed. The disadvantage of a 25 kt WOD in increased closure rate (paragraph 23) is also manifested in a like increase in arresting gear engaging speed. During these tests the average deviation in approach speed was less for a 25 kt WOD than for a 35 kt WOD. However, for both WOD values examined, the model A4D and F8U airplanes maintained an average approach speed approximately 4 kt higher than that recommended. It is reasonable to assume that fleet operations will encounter some recoveries when averages are to some degree higher than those determined under test conditions reported herein. Reduction in WOD will result in an equal increase in engaging speed plus the algebraic variation by individual pilots from recommended approach airspeed. The tendency is normally to be too fast.

27. Arresting Gear Capabilities for Increased Engaging Speeds. Enclosure (5), pages 1 and 2, list the minimum WOD requirements for various airplane/arresting gear combinations. These WOD requirements are based on the recommended approach speed at the maximum arrested landing gross weight. When the minimum WOD values listed in enclosure (5) are increased by 4 kt, it is evident that:

a. Only carriers equipped with MK 7, Mod 2-3 Constant Runout Arresting Gear (CROAG) with operative sheave dampers can utilize a 25 kt WOD for all carrier-based airplanes when at the maximum arrested landing gross weight.

b. Carriers equipped with MK 7, Mod 1-3 CROAG with operative sheave dampers can utilize a 25 kt WOD for the majority of carrier-based airplanes at gross weights less than the maximum.

c. Carriers equipped with any MK 7 CROAG without sheave dampers cannot utilize a 25 kt WOD for the majority of carrier-based airplanes.

28. Desirability of Standardization of WOD for Individual Carriers. From the pilot's point of view, the not uncommon practice of increasing the WOD for night operations is undesirable, since the pilot experiences different airflow conditions than he is normally accustomed to during day operations. The most desirable practice would be to standardize the prescribed WOD for all operations (day, night, routine recoveries and CarQual) in order to reduce the number of variables affecting the pilot during all carrier approaches. The value of WOD established should be that considered to be optimum in light of all previously mentioned factors that pertain to the particular ship. Emphasis should be placed on meticulously minimizing cross-wind during recoveries and avoiding an increase in WOD for night operations. Where group composition is predominantly jet, a standardized optimum WOD should be established as close to 25 kt as all considerations will permit. When the CVS composition is predominantly propeller aircraft and surface winds permit, a standardized optimum WOD of as near to 15 kt as is practicable should be established. For present carrier operations, if day and night recoveries can be standardized and maintained at a particular optimum WOD value for individual ships, although not necessarily as low as 25 kt, it is concluded that safety of recovery operations can be improved.

29. Present Application of Optimum WOD. An optimum WOD is that relative wind over the angle deck, with minimum practicable cross-wind component, which will minimize pilot control problems in the "burbles", and at the same time prove operationally feasible from a standpoint of airplane/arresting gear structural limitations, prevailing surface winds and operationally acceptable landing parameters. It has been determined that a 25 kt WOD meets many, although not all, of these criteria. Recovery operations must take into consideration deviations in airplane approach speed and overall accuracy of the AN/SPN-12 equipment, which is at best to within $\pm 3\%$. Air group training level and individual ship's arresting gear capability are major considerations. It is recommended that type commanders, fleet commanders and commanding officers be informed of the merits of a lower WOD, where feasible, and that utilization of a WOD that is optimum for a particular carrier be established with a view toward maintaining as low a value of WOD as is considered practicable.

RA1200001
(RSSH-31003)
FT2222-176

30. Future Considerations. The increased application of an optimum WOD for future carrier operations is dependent upon continued developmental effort. For example, the approach power compensator (APC), recently evaluated in the model F8U-1 airplane, will provide a significant improvement in approach airspeed control. Future installation of higher capacity arresting gear is a requirement to permit the use of lower values of WOD for some carriers. Continued emphasis on the many areas of the carrier landing improvement program will contribute toward more effective utilization of a WOD that is realistically optimum.

RA1200001
(RSSH-31003)
FT2222-176

CONCLUSIONS

31. It is concluded that:

a. From the pilot's viewpoint alone, 25 kt WOD for all jet airplanes and 15 kt WOD for all propeller airplanes (WOD parallel to the angled deck centerline) is optimum (paragraphs 11 and 12).

b. Any operationally feasible reduction in WOD that is standardized as optimum for individual carriers, and is near as practicable to 25 kt for jet and 15 kt for propeller airplanes, will improve safety of recovery operations (paragraph 28).

c. It is desirable to standardize the prescribed WOD for all operations for an individual carrier, within the limitations imposed by operational considerations (paragraphs 13, 15 and 28).

d. Prevailing surface winds preclude standardization of 15 kt WOD for propeller aircraft (paragraph 25).

e. OLS glide slope setting should be adjusted as a function of WOD to maintain airplane approach power setting relatively constant (paragraph 15).

f. For jet airplane recoveries, a $3\frac{1}{2}^{\circ}$ glide slope is required for 25 kt WOD, and a 4° glide slope is required for WOD values in excess of 30 kt (paragraph 15).

g. For propeller airplane recoveries, a $3\frac{1}{2}^{\circ}$ glide slope is satisfactory for a 15 kt WOD, and a 4° glide slope is desirable for a 25 kt WOD (paragraph 15).

32. As a result of comparative evaluation of WOD values of 35 kt and 25 kt for jet airplanes, it is concluded that, in addition to pilot control considerations, the following advantages of a 25 kt WOD are realized:

a. Reduction in the frequency of high landing gear loads (paragraphs 17 and 18).

b. Less deviation in alignment during the final approach and touchdown (paragraph 21).

RA1200001
(RSSH-31003)
FT2222-176

c. Improved flexibility of recovery operations (paragraph 25).

d. Improved approach airspeed control (paragraph 19).

33. As a result of comparative evaluation of WOD values of 35 kt and 25 kt for jet airplanes, it is concluded that the following disadvantages result from the approximately 10% increase in closure rate when using a 25 kt WOD:

a. Requirement to initiate wave-off earlier in the approach (paragraph 15).

b. Slight degradation in both average main gear touchdown distance from the theoretical as well as in touchdown deviation from the theoretical (paragraphs 21 and 23).

c. Increased bolter rate (paragraphs 22 and 23).

d. Airplane and/or arresting gear structural limits being exceeded on some carriers (paragraphs 26 and 27).

RECOMMENDATIONS

35. It is recommended that:

a. Emphasis be placed on reducing WOD values from those presently in use for fleet recovery operations to standardized WOD values for individual carriers as near to 25 kt for jet airplanes and 15 kt for propeller airplanes as is operationally practicable.

b. The varied adverse effects on the pilot of crosswind normal to the angle deck centerline be emphasized, and continuing action be taken to minimize crosswind during fleet recovery operations.

c. Emphasis be continued on design criteria and developmental effort to improve shipboard airflow characteristics and equipment utilized during the approach and recovery of aircraft.

PAUL H. RAMSEY



F. G. EDWARDS
By direction

RA1200001
(RSSH-31003)
FT2222-176

DATA RECORDED AND ASSOCIATED ACCURACIES OF DATA

<u>Item</u>	<u>External Instrumentation</u>	
	<u>Recorded by</u>	<u>Overall Accuracy (+)</u>
Approach speed	AN/SPN-12 radar	3%
Engaging speed	AN/SPN-12 radar; Mitchell camera	3%
Wind-Over-Deck		
Velocity	Calibrated boom anemometer	1 kt
Direction	Calibrated boom anemometer	3 deg
Sinking speed	Mitchell camera; cameraflex	2 fps
Airplane pitch attitude	Mitchell camera; cameraflex	1 deg
Airplane roll angle with respect to angle deck	Cameraflex	1 deg
Main gear touchdown distance	Mitchell camera Cameraflex	2 ft 5 ft
Off-center distance		
Ramp	Cameraflex	1 ft
Touchdown	Cameraflex	1 ft
Main gear to ramp clearance	Cameraflex	1 ft
Surface wind	Ship's aerology Log books	3 kt

<u>Item</u>	<u>Calculated</u>	
	<u>Method</u>	<u>Overall Accuracy (+)</u>
Airplane gross weight	Add associated fuel weight to basic airplane weight	200 lb
Theoretical main gear touchdown distance	See enclosure (10)	-10 to -15 ft

RA1200001
(RSSH-31003)
FT2222-176

<u>Item</u>	<u>Calculated</u> <u>Method</u>	<u>Overall</u> <u>Accuracy (±)</u>
Theoretical sinking speed	See enclosure (10)	2 fps
Bolter rate	See enclosure (10)	2%

<u>Item</u>	<u>Observed</u>	<u>Overall</u> <u>Accuracy (±)</u>
Ship's pitch and roll		1/3 deg
Arresting gear weight setting		500 lb

Model F8U-1 Airplane, BuNo 143749

ARRESTED LANDING TABULATED DATA

MK 7 Mod 2-3 CROAG with Sheave and Anchor Dampers

USS CORAL SEA (CVA-43)

LANDING NUMBER	51	52	53	54	55	56	57	58	59	60
TYPE LANDING	T&G	A	T&G		B	A	T&G			A
FUEL										
AIRPLANE GROSS WEIGHT	(lb) 1900	1800	4200	3900	3700	3600	3900	3700	3500	3100
ARRESTING GEAR WEIGHT SETTING	(lb) 20300	20200	22600	22300	22100	22000	22300	22100	21900	21500
WIRE NO.	(lb) 20500	20000	22000	22000	22000	22000	22000	22000	22000	21500
BASIC GLIDE SLOPE ANGLE	(°) 4	2	-	-	-	4	-	-	-	4
LENS ROLL ANGLE	(°) 3									
SHIP'S PITCH (-STERN DOWN)	(°) -0.1		0.0	-0.1				0.0	-0.1	-0.2
SHIP'S ROLL (-ROLL STRBD)	(°) -1.0	-1.2	-1.6	-1.0	-0.8	-1.7	-0.4	-0.4	-1.0	-0.4
WIND-OVER-DECK										
VELOCITY	(kt) 35	37	35	34				35		36
DIRECTION	(°) 345		350							
SURFACE WIND (APPROX)	(kt) 20		27				25			
APPROACH SPEED	(kt) 138	133	150	141	147	140	142	140	140	137
ENGAGING SPEED	(kt) 103	96	115	107	113	106	108	105	105	101
PITCH ATTITUDE	(°) 6.1	7.1	4.0	6.1	4.6	4.6	7.9	3.8	8.1	5.2
AIRPLANE ROLL ANGLE W/RESP										
TO ANGLE (°)	-3.5	-3.1	-4.5	-6.8	-2.8	-3.9	-2.7	-1.9	-2.8	-7.5
SINKING SPEED	(fps)									
MITCHELL CAMERA	13.0	10.1	12.7	14.7		13.0	16.5		15.9	13.4
CAMERAFLEX	12.6	10.7	14.1	15.4	13.2	13.5	16.5	14.1	13.7	14.7
THEORETICAL	13.7	12.1	14.4	13.6	13.3	13.6	12.6	12.5	13.3	12.7
MAIN GEAR TOUCHDOWN DISTANCE	(ft)									
ACTUAL	206	172	217	202	261	248	198	183	208	224
THEORETICAL	196	193	206	196	203	209	190	199	187	202
MAIN GEAR TO RAMP CLEARANCE	(ft) 16.5	13.0	-	-	-	-	-	-	-	-
OFF-CENTER DISTANCE (- PORT)	(ft)									
RAMP	-15.5	12.5	-	-	-	-	-	-	-	-
TOUCHDOWN	3.0	-5.0	0.0	6.0	5.0	-1.0	-1.0	0.0	0.0	8.0

Model A4D-2 Airplane, BuNo 142678

ARRESTED LANDING TABULATED DATA

MK 7 Mod 2-3 CROAG with Sheave and Anchor Dampers

USS CORAL SEA (CVA-43)

LANDING NUMBER	51	52	53	54	55	56	57	58	59	60	61	62	63
TYPE LANDING	T&G	A	T&G										A
FUEL	(lb)	1500	1400	3500	3200	2800	2500	2400	2200	1600	1500	1400	1300
AIRPLANE GROSS WEIGHT	(lb)	11500	11400	13500	13200	12800	12500	12400	12200	11600	11500	11400	11300
ARRESTING GEAR WEIGHT SETTING	(lb)	12000	12000	14000	14000	13500	13000	13000	13000	12500	12000	12000	12000
WIRE NO.			4										1
BASIC GLIDE SLOPE ANGLE	(°)	4											
LENS ROLL ANGLE	(°)	4	3/4										
SHIP'S PITCH (- STERN DOWN)	(°)	-0.1		-0.2		-0.1	0.0			-0.1	0.0	-0.1	-0.1
SHIP'S ROLL (- ROLL STRD)	(°)	-1.0	-1.0	-0.7	0.3	-0.2	-0.3	-1.1	-0.5	-1.0	0.1	-0.5	-1.0
WIND-OVER-DECK													
VELOCITY	(kt)	35		36	34		35	37		36	38	36	37
DIRECTION	(°)	350		355	350	345		359	355	350			
SURFACE WIND (APPROX)													
APPROACH SPEED	(kt)	117	121	130	130	130	126	127	124	119	117	119	116
ENGAGING SPEED	(kt)	82	86	94	96	96	91	90	87	83	79	83	79
PITCH ATITUDE	(°)	10.1	12.1	8.8	12.1	6.1	11.0	6.0	11.2	10.0	12.1	12.1	9.1
AIRPLANE ROLL ANGLE W/ RESP													
to ANGLE DECK (- PORT)	(°)	-1.8	0.0	-1.1	-1.1	0.6	2.7	1.0	-4.2	1.6	-4.2	-0.9	-3.1
SINKING SPEED	(fps)												
MITCHELL CAMERA		11.7	10.8		13.0	11.4	12.7	12.9	13.6	13.0	11.6	10.0	13.7
CAMERA FLEX		11.1	11.2	12.8	13.4	13.6	11.7	10.8	14.2	13.5	10.9	10.3	13.2
THEORETICAL		10.2	11.8	11.9	11.4	11.8	11.0	10.9	10.8	10.1	9.3	10.2	9.8
MAIN GEAR TOUCHDOWN DISTANCE	(ft)												
ACTUAL		162	172	188	179	299	170	209	160	160	171	157	143
THEORETICAL		229	227	235	220	234	217	235	228	225	220	219	232
MAIN GEAR TO RAMP CLEARANCE	(ft)												
OFF-CENTER DISTANCE (- PORT)	(ft)												
RAMP													
TOUCHDOWN		-1.0	-2.0	-2.0	10	-1.0	-1.0	0.0	3.0	-6.0	1.0	0.0	3.0

Model A4D-2 Airplane, BuNo 142120

ARRESTED LANDING TABULATED DATA

MK 7 Mod 2-3 CROAG with Sheave and Anchor Dampers

USS CORAL SEA (CVA-43)

ARRESTED LANDING TABULATED DATA

MK 7 Mod 2-3 CROAG with Sheave and Anchor Dampers

USS CORAL SEA (CVA-43)

[illegible]

USS CORAL SEA (CVA-43)

Page 8 of 9
Enclosure (2)

RA1200001
(RSSH-31003)
FT2222-176

Model A4D-2 Airplane, BuNo 142089

ARRESTED LANDING TABULATED DATA

MK 7 Mod 2-3 CROAG with Sheave and Anchor Dampers

USS CORAL SEA (CVA-43)

LANDING NUMBER	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
TYPE LANDING	TAG							A	TAG									A
FUEL	(lb)	2600	2400	2000	1800	1700	1600	1500	1400	1300	1200	1100	1000	900	800	700	600	500
AIRPLANE GROSS WEIGHT	(lb)	13000	12800	12600	12400	12200	12000	11800	11600	11400	11200	11000	10800	10600	10400	10200	10000	9800
ARRESTING GEAR WEIGHT SETTING	(lb)	13000	12800	12600	12400	12200	12000	11800	11600	11400	11200	11000	10800	10600	10400	10200	10000	9800
WIRE NO.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BASIC GLIDE SLOPE ANGLE	(°)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
LFNS ROLL ANGLE	(°)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
SHIP'S PITCH (-STEER DOWN)	(°)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
SHIP'S ROLL (-ROLL STEER)	(°)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
WIND OVER DECK		34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
VELOCITY	(kt)	36	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
DIRECTION	(°)	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350	350
SURFACE WIND (A PR X)	(kt)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
APPROACH SPEED	(kt)	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
ENGAGING SPEED	(kt)	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
PITCH ATTITUDE	(°)	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
AIRPLANE ROLL ANGLE W/ SEEP	(°)	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6
TO ANGLE DECK (-FOOT)	(ft)	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
SINKING SPEED	(ft/s)	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
MITCHELL CAMERA		11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
CAMERALEX		11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
THEORETICAL		11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
MAIN GEAR TOUCHDOWN DISTANCE	(ft)	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236
ACTUAL		236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236
THEORETICAL		236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236
MAIN GEAR TO RAMP CLEARANCE	(ft)	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236
MAIN GEAR TO RAMP CLEARANCE	(ft)	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236
OFF-CENTER DISTANCE (-P-RT)	(ft)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
RAMP		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOUCHDOWN		6.0	4.0	2.0	1.0	1.0	2.0	3.0	2.0	5.0	8.0	3.0	-3.0	3.0	2.0	4.0	5.0	-1.0

RA1200001
(RSSH-31003)
FT2222-176

SUMMARY OF OPTIMUM WIND-OVER-DECK LANDINGS

USS MIDWAY (CVA-41)
USS RANGER (CVA-61)
USS CORAL SEA (CVA-43)
USS SARATOGA (CVA-60)

<u>Aircraft Carrier</u>	<u>Model Airplane</u>	<u>BuNo</u>	<u>Touch & Go's</u>	<u>Arrests</u>	<u>Bolters</u>
CVA-41	F8U-1	143749	42	7	5
	A4D-2	142678	41	8	3
	A3D-2P	142668	21	9	3
	TF-1	136766	28	2	0
CVA-61	F8U-2	145588	49	6	1
	A4D-2	142678	44	6	0
	F4D-1	139143	28	4	0
CVA-43	F8U-2	145557	59	9	1
	F8U-1	143749	51	8	1
	A4D-2	142678	54	9	0
	A4D-2	142120	40	7	0
	A4D-2	142089	59	9	0
CVA-60	F8U-1	143749	3	1	0
			*14	*2	*0
	A4D-2	142089	8	1	0
			<u>*10</u>	<u>*2</u>	<u>*0</u>
TOTAL			551	90	14

*Night Landings

Enclosure (3)

RA1200001
(RSSH-31003)
FT2222 176

SUMMARY OF AIRPLANE LANDING PARAMETER ANALYSIS
USS CORAL SEA (CVA-43)

AIRPLANE DATA		678		120		089		557		749		ALL	
WIND-OVER-DECK	(kt)	25	35	ALL	25	35	ALL	25	35	ALL	25	35	ALL
APPROACH SPEED	(kt)												
V_A		126	124	127	128	130	130	142	143	140	140	142	141
$3\sigma V_A$		13	12	11	11	5	7	7	6	8	12	9	11
ΔV_A		+2	+1	+2	+5	+5	+5	+5	+5	+4	+4	+4	+4
V_{L_A}		8	7	8	8	7	12	11	10	13	7	8	9
\bar{V}		26	37	61	10	29	47	28	40	68	18	43	61
SINKING SPEED		(fpm)											
\bar{V}_S		12.0	12.5	13.0	13.5	13.5	12.0	12.5	12.5	13.0	14.0	14.5	14.0
$3\sigma V_S$		4.0	4.0	4.0	6.0	5.5	4.5	4.5	4.5	5.5	5.5	5.0	6.0
\bar{V}_{L_S}		25	35	60	18	29	47	28	40	68	18	43	61
ΔV_S		+0.5	+1.5	+1.0	+1.5	+2.5	+2.0	+1.0	0.0	+0.5	+1.5	+1.0	+1.0
V_{L_S}		4.0	4.0	4.0	4.0	6.0	5.5	4.5	4.5	5.5	5.5	5.0	6.0
\bar{V}_{L_S}		25	35	60	18	29	47	28	40	68	18	43	61
OFF-CENTER DISTANCE AT TOUCHDOWN		(ft)											
\bar{X}		0	0	0	-1	-1	-1	+5	+1	+1	+1	+1	+1
$3\sigma \bar{X}$		8	9	8	9	11	6	7	7	11	10	10	9
$\Delta \bar{X}$		25	35	60	18	29	47	28	40	68	18	43	61
MAIN GEAR TOUCHDOWN OR TOWERS FROM RAMP		(ft)											
\bar{Z}		135	175	100	205	205	195	210	200	195	205	205	195
$3\sigma \bar{Z}$		115	90	105	95	90	105	60	85	110	110	110	115
$\Delta \bar{Z}$		-55	-55	-55	-55	-55	-55	-55	-55	-55	-55	-55	-55
$3\sigma \Delta \bar{Z}$		105	85	95	90	80	85	100	60	90	100	100	100
\bar{X}		25	35	60	18	29	47	28	40	68	18	43	61
OFF-CENTER DISTANCE AT RAMP		(ft)											
\bar{Y}		+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5	+1.5
$3\sigma \bar{Y}$		7.0	9.5	8.5	8.0	11.0	16.0	4.5	4.0	7.5	7.5	7.5	7.5
\bar{X}		15	16	31	12	17	29	21	15	28	46	48	94
MAIN GEAR TO RAMP CLEARANCE		(ft)											
\bar{W}/R		15.0	15.5	17.0	20.0	14.5	17.0	14.5	17.0	14.5	15.0	14.5	14.5
$3\sigma \bar{W}/R$		11.5	10.5	9.5	9.0	8.0	8.0	10.5	10.5	10.5	10.5	10.0	10.0
\bar{X}		15	16	31	12	17	29	21	15	28	46	48	94
AIRPLANE ROLL ANGLE		(deg)											
$\bar{\theta}$		-0.5	-0.5	-1.0	-2.5	-2.0	-1.5	-2.5	-2.0	-1.0	-1.5	-1.5	-1.5
$3\sigma \bar{\theta}$		3.5	3.5	6.0	7.0	7.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
\bar{X}		24	35	59	18	29	47	27	39	66	69	103	172

Enclosure (4)

MINIMUM WOD REQUIREMENTS FOR MOST CRITICAL JET AIRPLANES

RA1200001
(RSSH-31003)
FT2222-176

Arresting Gear	Airplanes	Max Arrested Landing Wt (lb)	Recom- mended Approach Spd (kt)	Min WOD Required (kt)		Limit Based On
				Glide Slope 4°	Angle 3½°	
MK7, Mod 1-3 95'Span without Sheave Dampers	F8U-1P	22,000	144	34	34	Arresting Gear Capacity
	F8U-1/-2	22,000	139	29	29	Arresting Gear Capacity
	A3D-1/-2	50,000	131	27	27	Arresting Gear Capacity
MK7, Mod 1-3 120'Span without Sheave Dampers	F8U-1P	22,000	144	29	29	Arresting Gear Capacity
	F8U-1/-2	22,000	139	24	24	Arresting Gear Capacity
	A3D-1/-2	50,000	131	23	23	Arresting Gear Capacity
MK7, Mod 2-3 without Sheave Dampers	F8U-1P	22,000	144	27	27	Arresting Gear Capacity
	F8U-1/-2	22,000	139	22	22	Arresting Gear Capacity
	A3D-1/-2	50,000	131	22	22	Arresting Gear Capacity
MK7, Mod 1-3 95'Span with Sheave Dampers	A4D-2	13,750	131	24	24	Hook Strength
	A3D-1/-2	50,000	131	23	23	Arresting Gear Capacity
	F4D-1	19,700	135	25	20	Landing Gear Strength
MK7, Mod 1-3 120'Span with Sheave Dampers	A3D-1/-2	50,000	131	23	23	Arresting Gear Capacity
	F4D-1	19,700	135	25	20	Landing Gear Strength
	A4D-2	13,750	131	21	20	Landing Gear Strength
MK7, Mod 2-3 with Sheave Dampers	F4D-1	19,700	135	25	20	Landing Gear Strength
	A3D-1/-2	50,000	131	21	16	Landing Gear Strength
	A4D-2	13,750	131	21	16	Landing Gear Strength

- NOTE: 1. Recommended approach speed extracted from applicable flight handbooks.
2. Minimum WOD required determined from the limit engaging speed contained in Aircraft Recovery Bulletins effective 2 Jan 1962.
3. Data excludes the model FJ-4 series, F9F-8 series and F11F-1 airplanes.

MINIMUM WOD REQUIREMENTS FOR MOST CRITICAL PROPELLER AIRPLANES

Arresting Gear	Airplanes	Max Arrested Landing		Recommended Approach Spd Req'd		Limit Based On
		Wt (lb)	(kt)	(kt)	(kt)	
MK5, Mod 3	AD-5W	17,500	100	16	Hook Strength	
	S2F-3	24,200	95	12	Hook Strength	
	AD-5W	17,500	100	17	Hook Strength	
	S2F-3	24,200	95	13	Hook Strength	
MK7, Mod 1-3 95' Span without Sheave Dampers	AD-5W	17,500	100	14	Hook Strength	
	S2F-3	24,200	95	10	Hook Strength and Airplane Accel.	
	AD-5W	17,500	100	15	Hook Strength	
	S2F-3	24,200	95	11	Airplane Accel.	
MK7, Mod 1-3 95' Span with Sheave Dampers	AD-5W	17,500	100	13	Hook Strength	
	S2F-3	24,200	95	9	Airplane Accel.	
	AD-5W	17,500	100	18	Hook Strength	
	S2F-3	24,200	95	14	Airplane Accel.	
MK7, Mod 2-3 with Sheave Dampers	AD-5W	17,500	100	10	Hook Strength	
	S2F-3	24,200	95	5	Airplane Accel.	

NOTE: 1. Recommended approach speed extracted from applicable flight handbooks.
2. Minimum WOD required determined from limit engaging speed contained
in Aircraft Recovery Bulletins effective 2 Jan 1962.

RA1200001
(RSSH-31003)
FT2222-176

ANNUAL PERCENTAGE FREQUENCY
OF SURFACE WIND IN CARRIER OPERATING AREAS

<u>Operating Area</u>	<u>10 Kt or Less</u>	<u>16 Kt or Less</u>
San Diego-Los Angeles	46	75
Los Angeles-San Francisco	43	67
East Formosa Coast	50	69
East Okinawa Coast	25	55
East Japan Coast	37	61
Southeast Asia Coast		
(22°N 118°E)	59	70
(18°N 108°E)	59	81
(12°N 112°E)	51	63
(7°N 108°E)	57	83
(9°N 102°E)	73	90
Norfolk-Jacksonville	27	53
Jacksonville-Gtmo	56	82
East Mediterranean	66	83
West Mediterranean	61	78
North Atlantic		
(58°N 18°W)	20	42
(53°N 33°W)	21	44
(53°N 18°W)	18	40
(43°N 42°W)	22	35
(33°N 48°W)	35	63
(43°N 17°W)	32	58
ALL	43.0	64.5

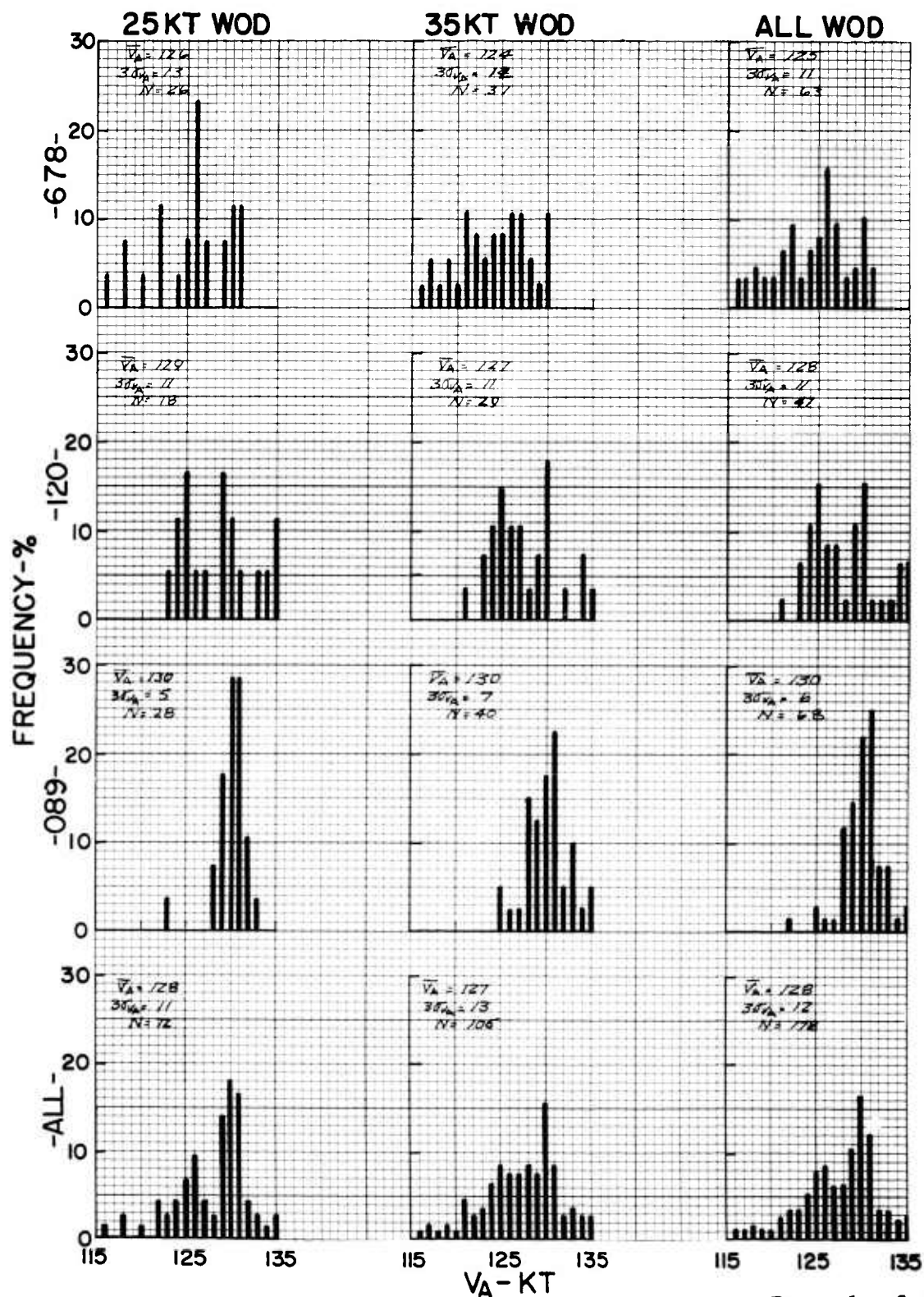
Data obtained from Naval Weather Service, Anacostia, 1 Feb 1962.

Enclosure (6)

RA1200001
(RSSH-31003)
FT2222-176

Model A4D-2 Airplane
BuNo 142678, 142120 and 142089

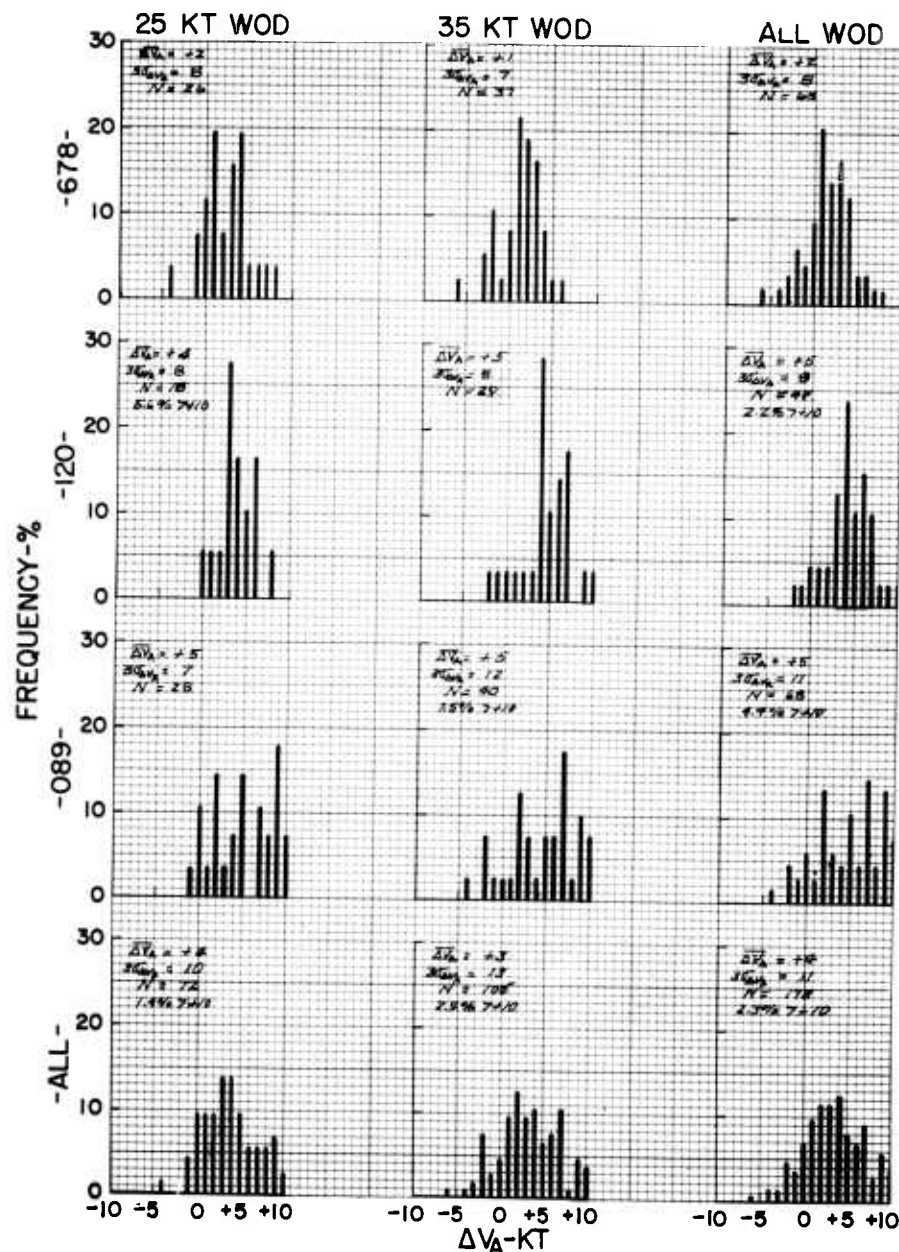
FREQUENCY DISTRIBUTION OF AIRPLANE APPROACH SPEED



RA1200001
(RSSH-31003)
FT2222-176

Model A4D-2 Airplane
BuNo 142678, 142120 and 142089

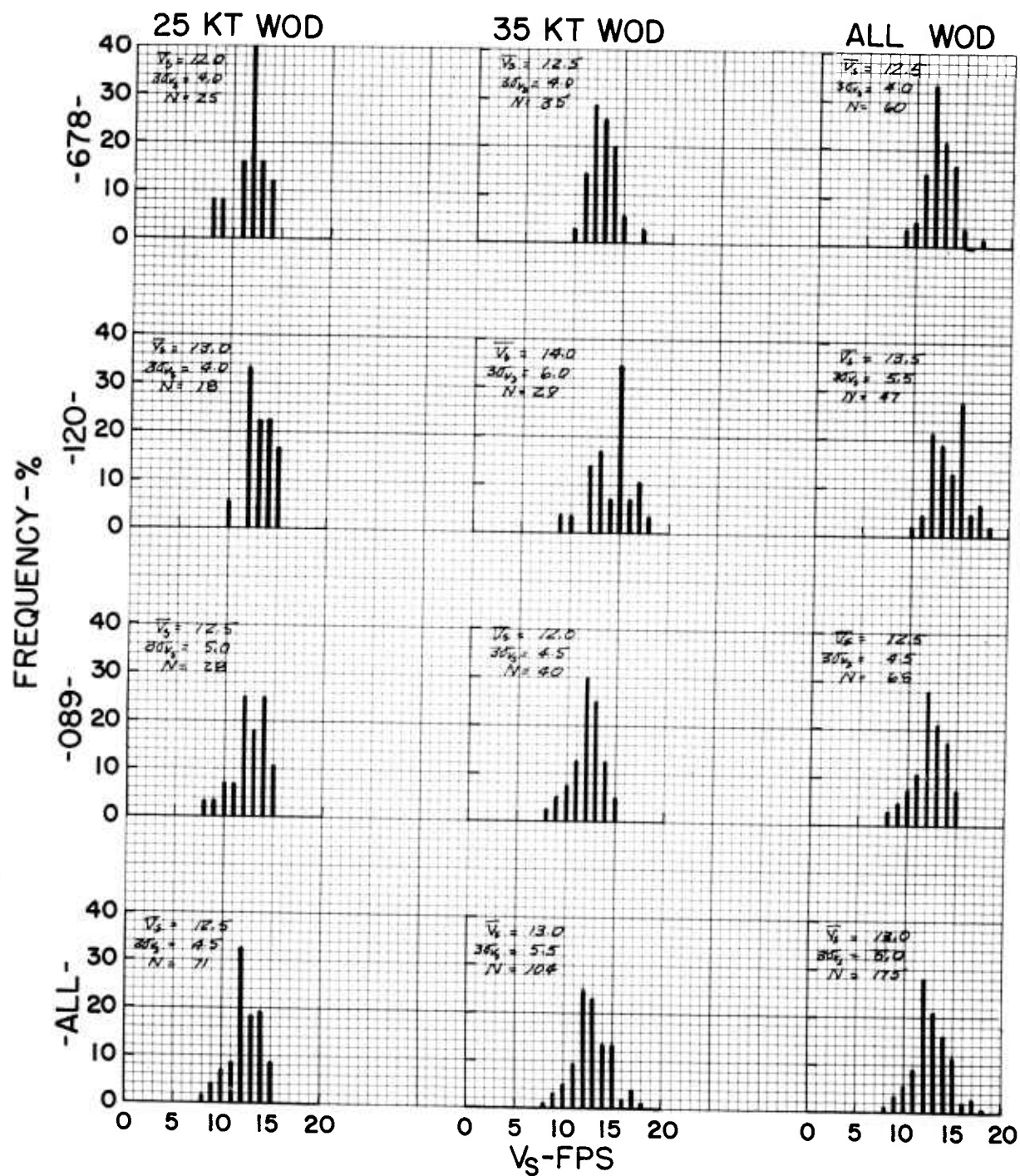
FREQUENCY DISTRIBUTION OF DEVIATION FROM
RECOMMENDED AIRPLANE APPROACH SPEED



RA1200001
(RSSH-31003)
FT2222-176

Model A4D-2 Airplane
BuNo 142678, 142120 and 142089

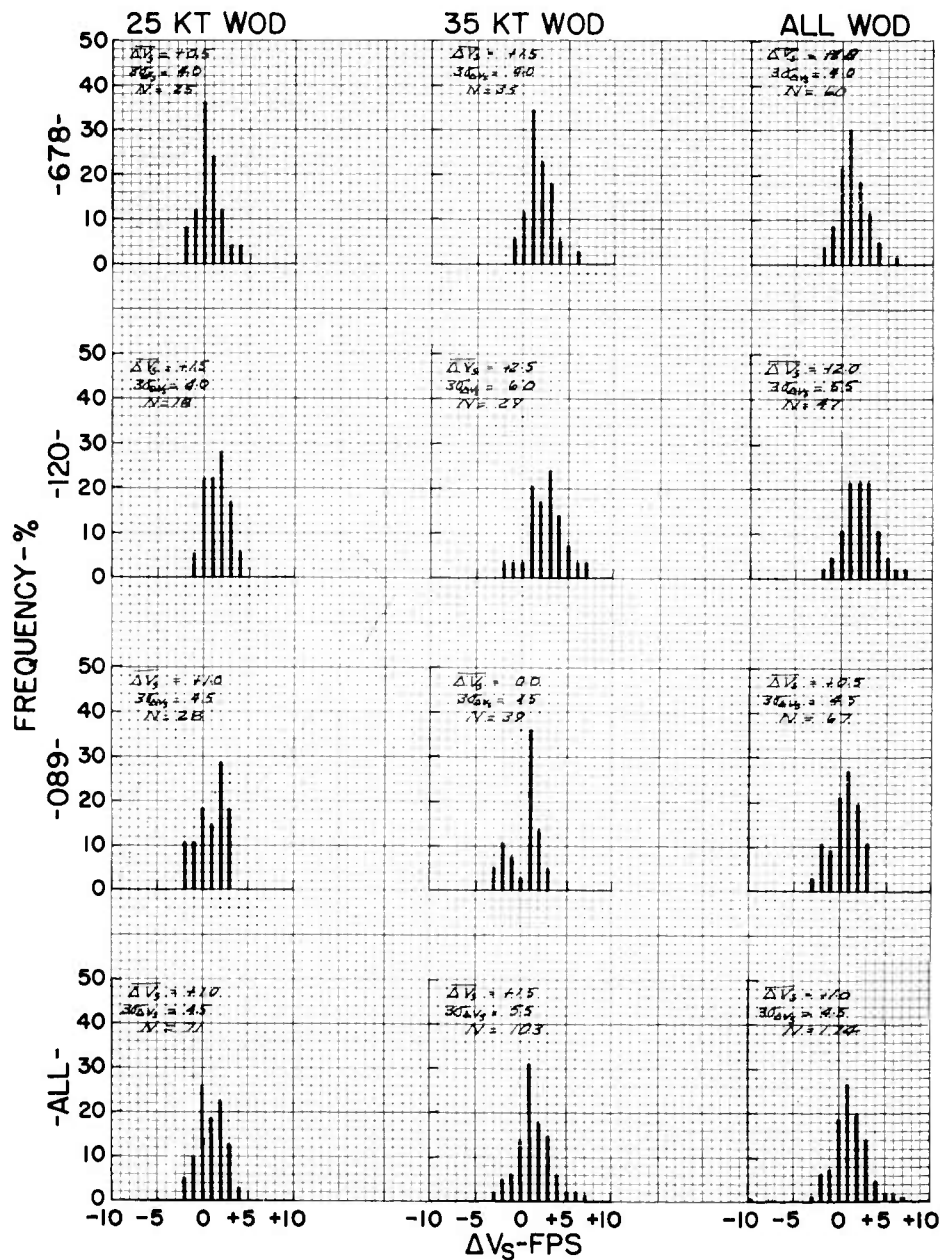
FREQUENCY DISTRIBUTION OF AIRPLANE SINKING SPEED



RA1200001
(RSSH-31003)
FT2222-176

Model A4D-2 Airplane
BuNo 142678, 142120 and 142089

FREQUENCY DISTRIBUTION OF DEVIATION FROM
THEORETICAL AIRPLANE SINKING SPEED

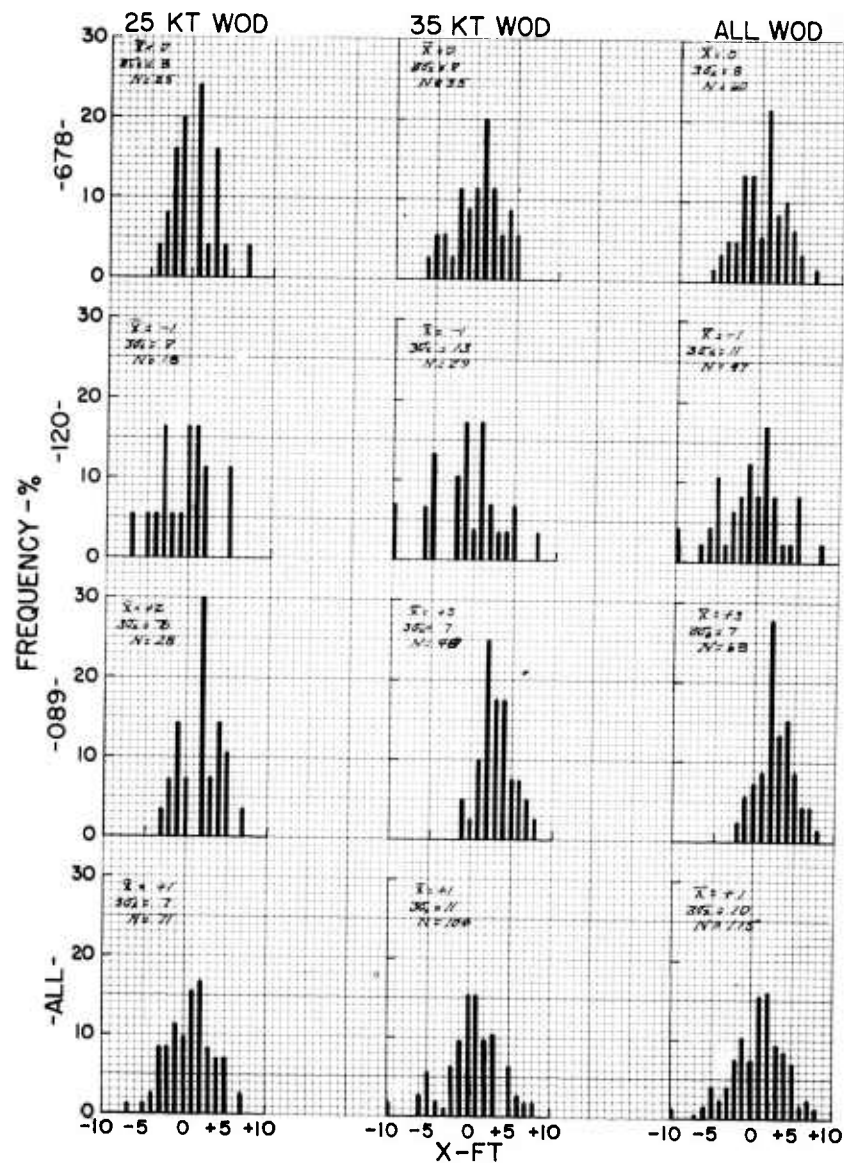


RA1200001
(RSSH-31003)
FT2222- 176

Model A4D-2 Airplane
BuNo 142678, 142120 and 142089

FREQUENCY DISTRIBUTION OF AIRPLANE OFF-CENTER DISTANCE AT TOUCHDOWN

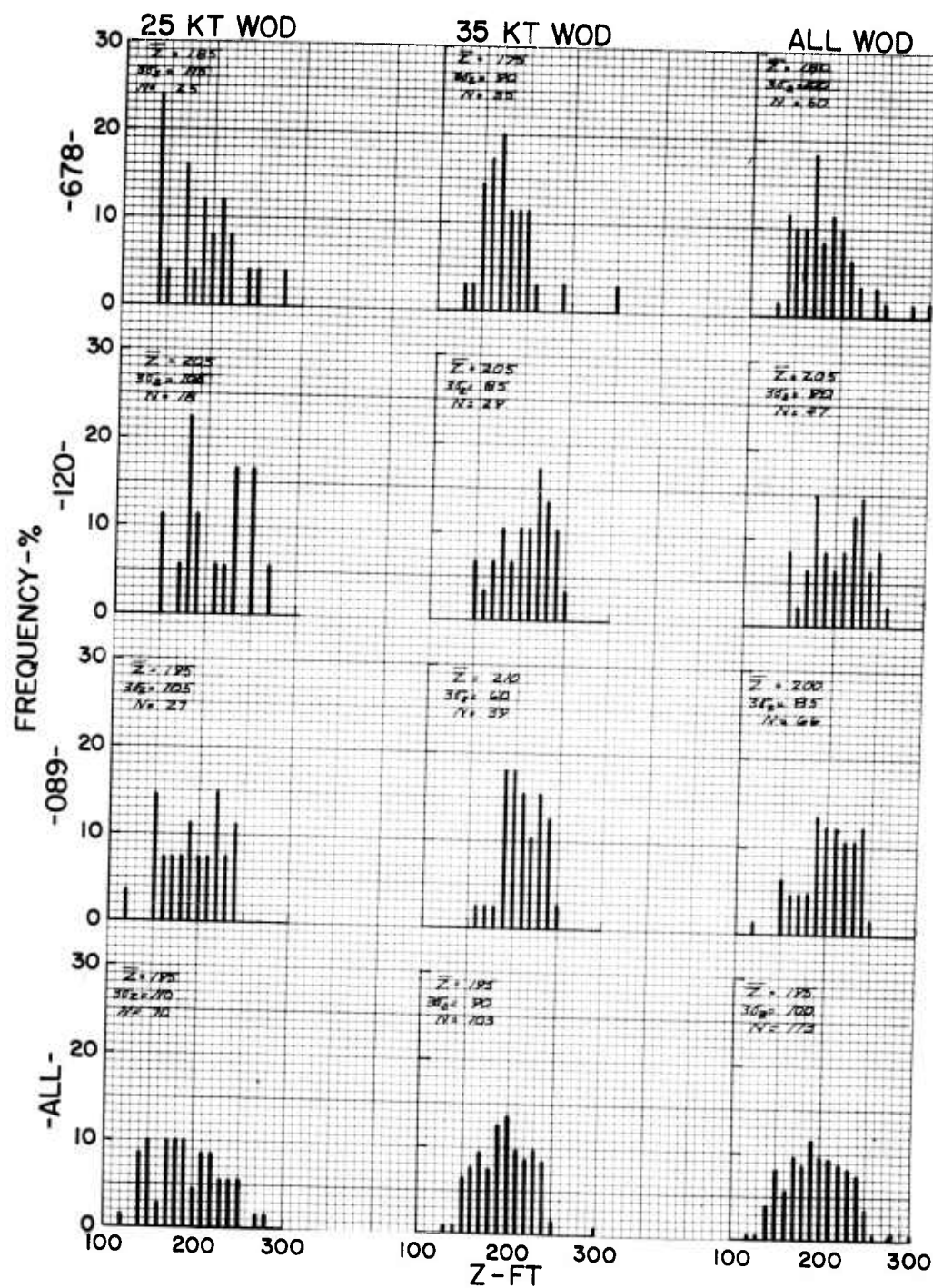
LEGEND: + Starboard
- Port



RA1200001
(RSSH-31003)
FT2222- 176

Model A4D-2 Airplane
BuNo 142678, 142120 and 142089

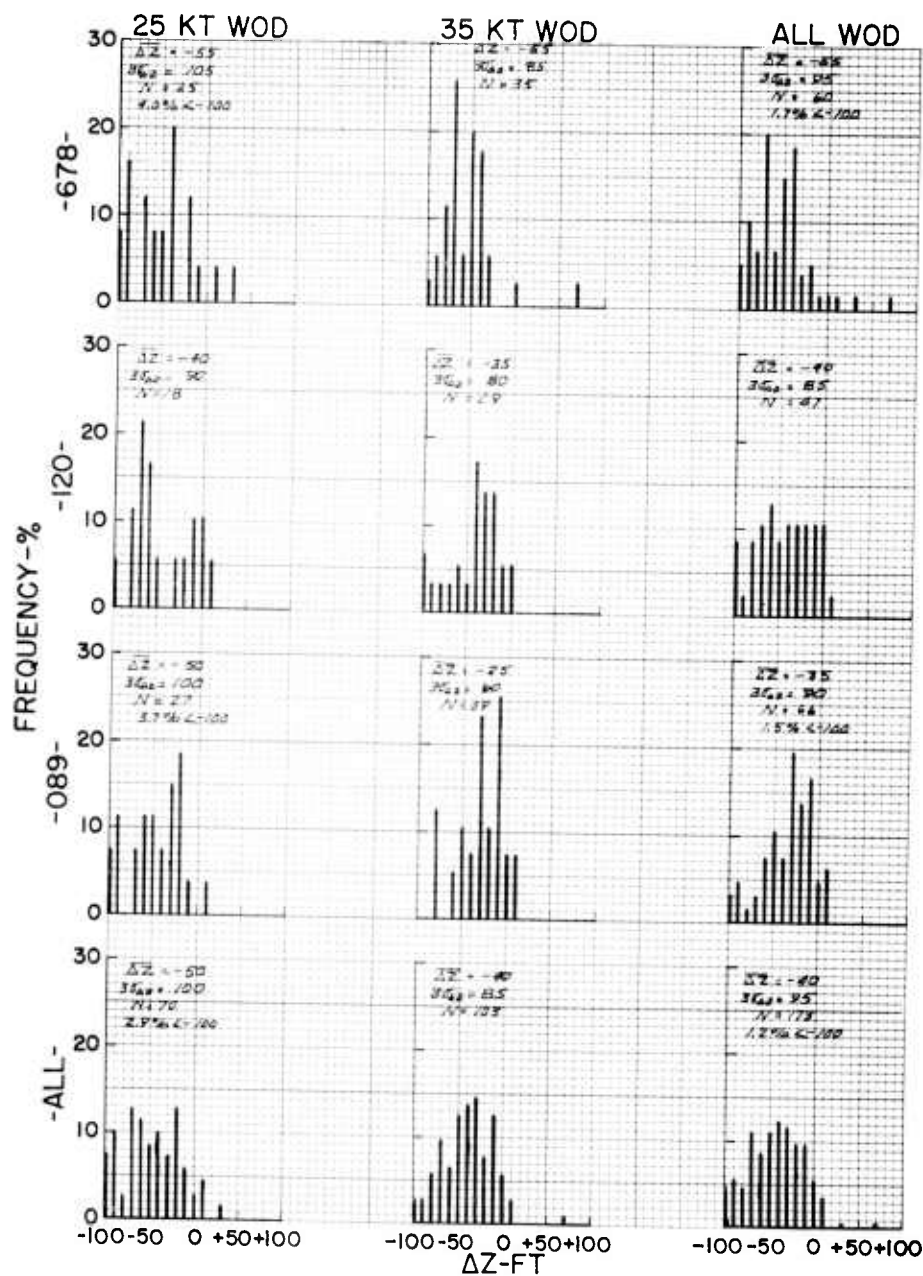
FREQUENCY DISTRIBUTION OF AIRPLANE MAIN GEAR TOUCHDOWN DISTANCE FROM RAMP



RA1200001
(RSSH-31003)
FT2222- 176

Model A4D-2 Airplane
BuNo 142678, 142120 and 142089

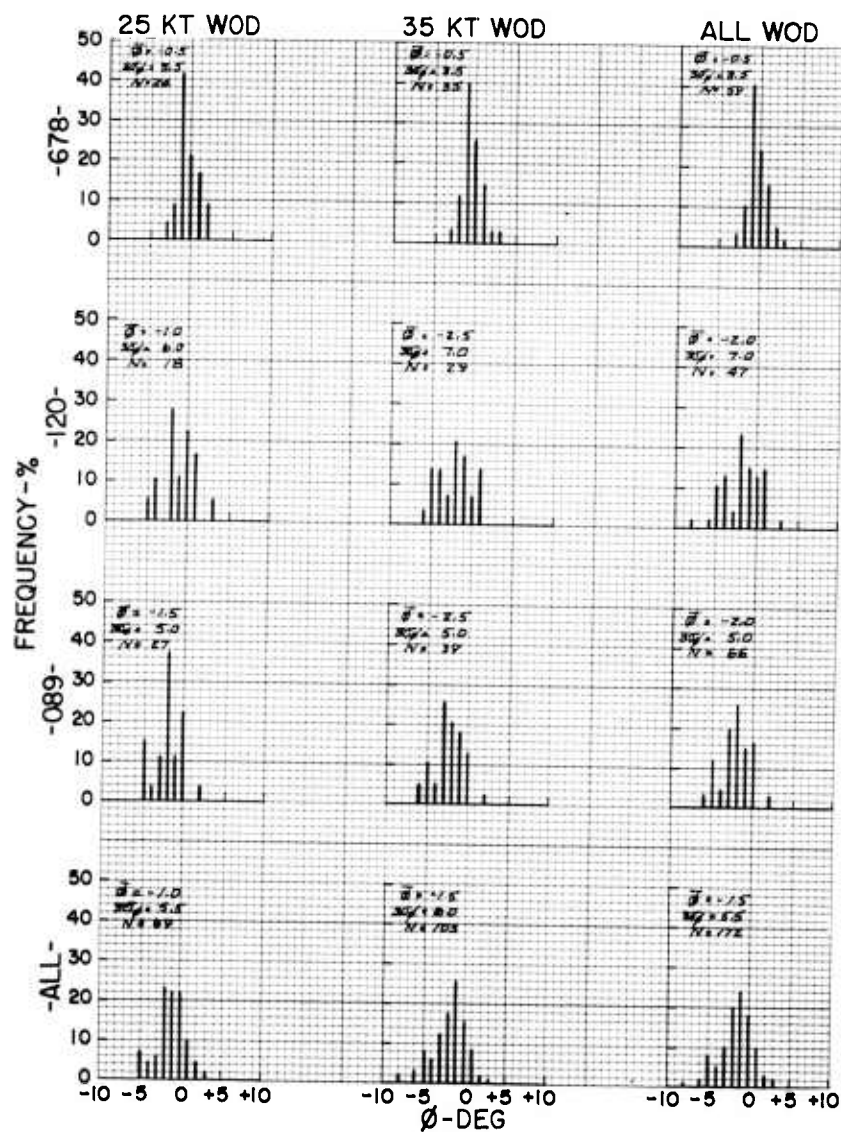
FREQUENCY DISTRIBUTION OF DEVIATION FROM
THEORETICAL AIRPLANE MAIN GEAR TOUCHDOWN DISTANCE
FROM RAMP



RA1200001
(RSSH-31003)
FT2222-176

Model A4D-2 Airplane
BuNo 142678, 142120 and 142089

FREQUENCY DISTRIBUTION OF AIRPLANE ROLL ANGLE

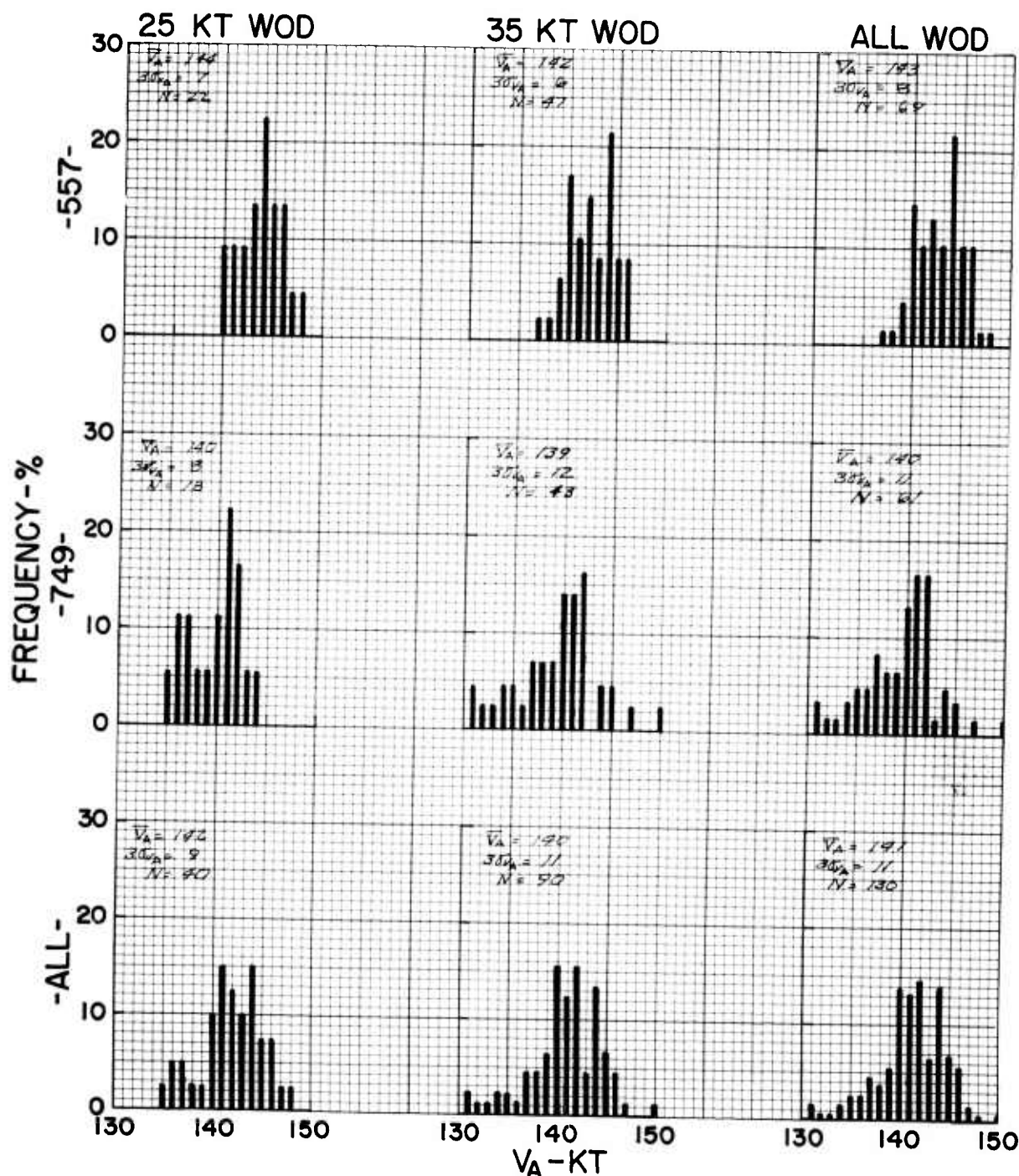


LEGEND: + Starboard
- Port

RA1200001
(RSSH-31003)
FT2222-176

Model F8U-2 Airplane, BuNo 145557
Model F8U-1 Airplane, BuNo 143749

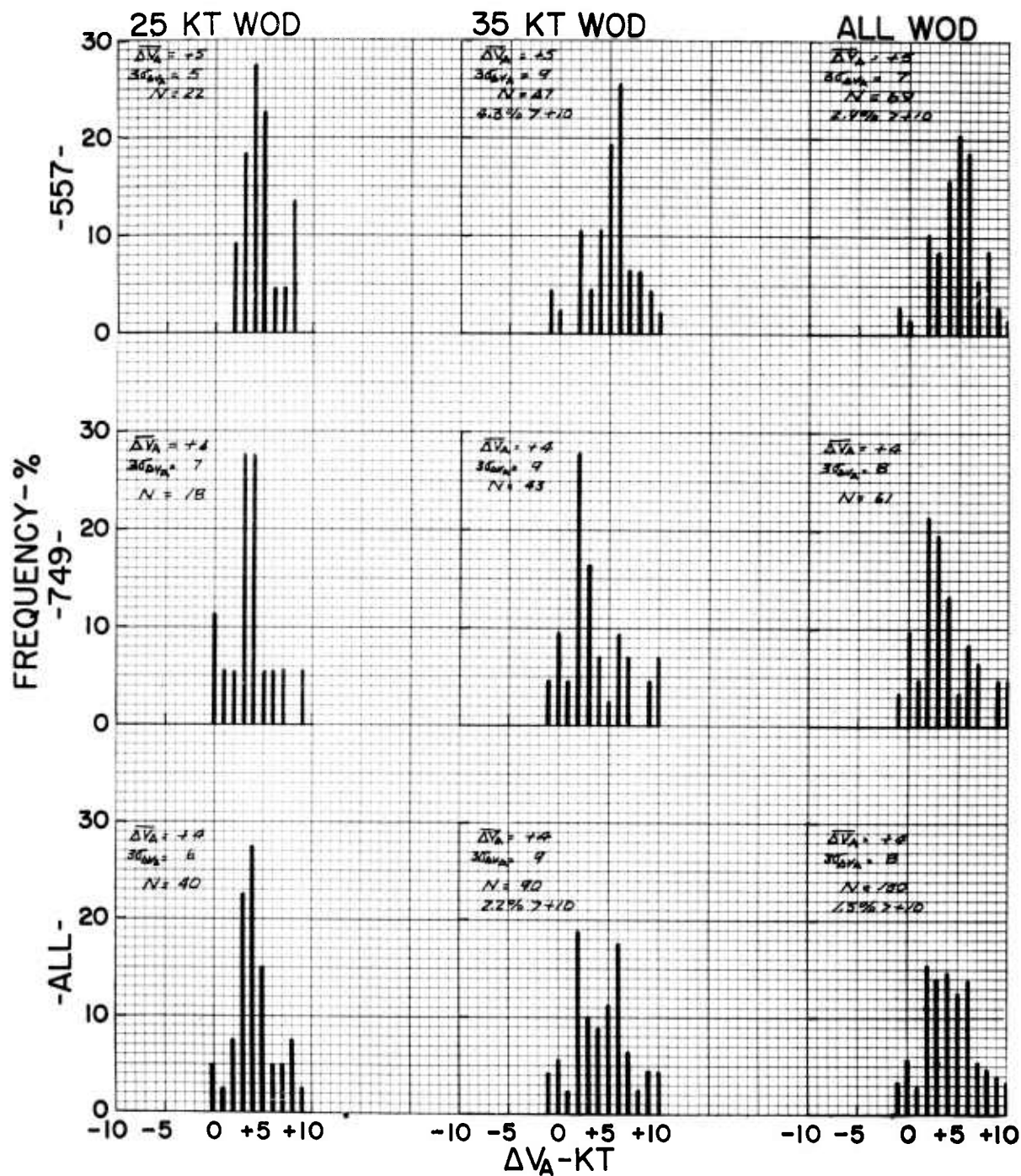
FREQUENCY DISTRIBUTION OF AIRPLANE APPROACH SPEED



RA1200001
(RSSH-31003)
FT2222-176

Model F8U-2 Airplane, BuNo 145557
Model F8U-1 Airplane, BuNo 143749

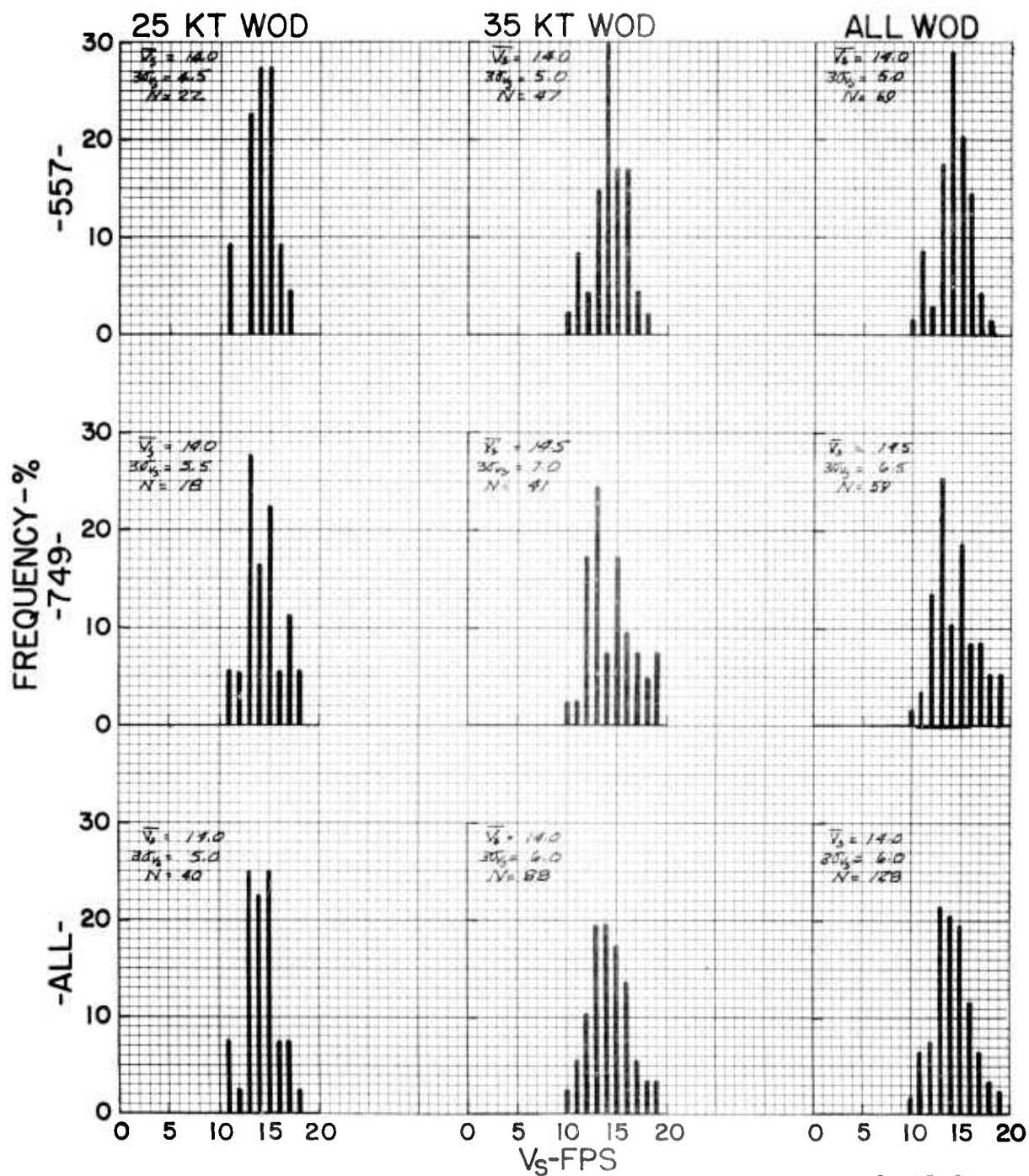
FREQUENCY DISTRIBUTION OF DEVIATION FROM
RECOMMENDED AIRPLANE APPROACH SPEED



RA1200001
(RSSH-31003)
FT2222- 176

Model F8U-2 Airplane, BuNo 145557
Model F8U-1 Airplane, BuNo 143749

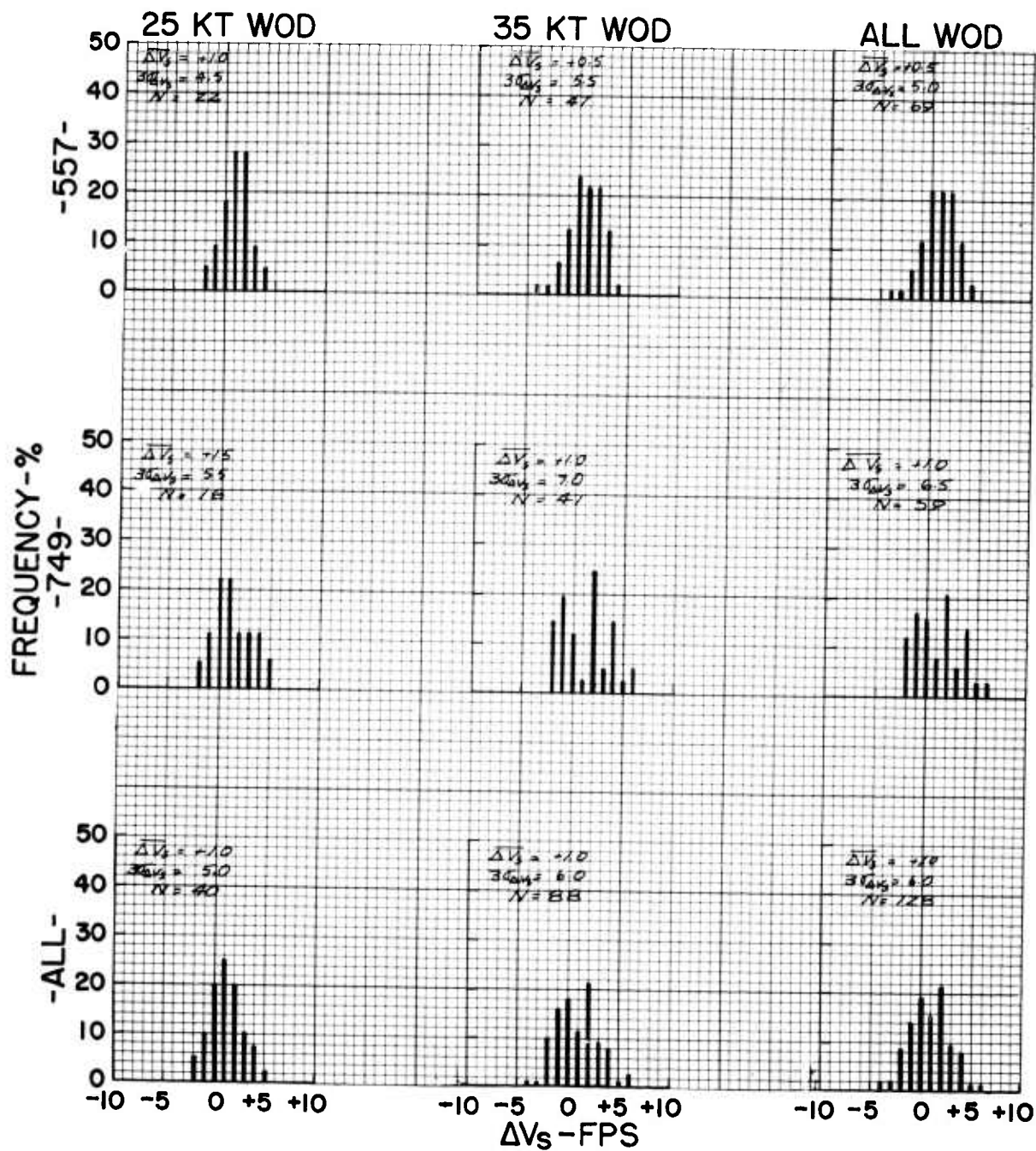
FREQUENCY DISTRIBUTION OF AIRPLANE SINKING SPEED



RA1200001
(RSSH-31003)
FT2222- 176

Model F8U-2 Airplane, BuNo 145557
Model F8U-1 Airplane, BuNo 143749

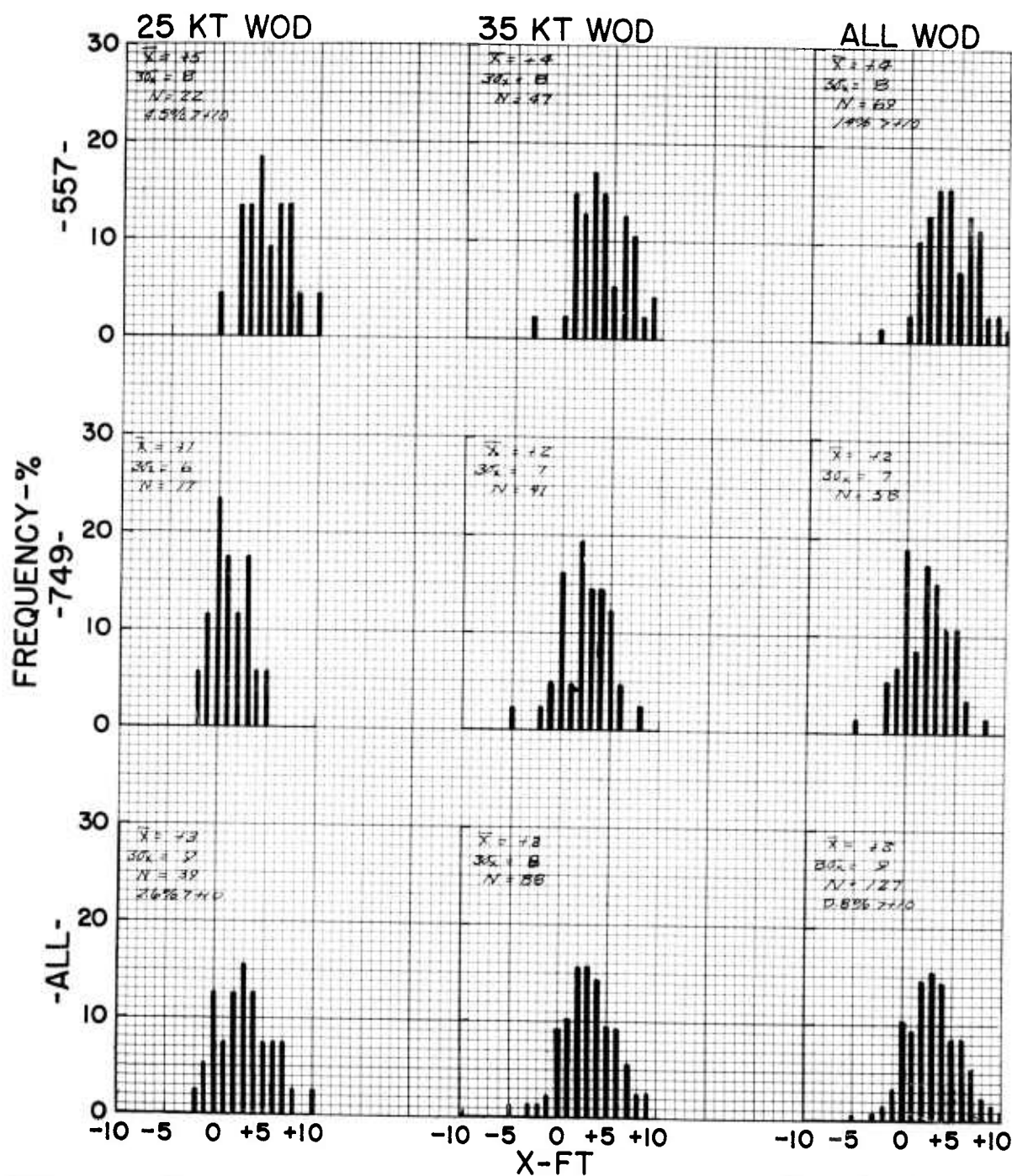
FREQUENCY DISTRIBUTION OF DEVIATION FROM
THEORETICAL AIRPLANE SINKING SPEED



RA1200001
(RSSH-31003)
FT2222-176

Model F8U-2 Airplane, BuNo 145557
Model F8U-1 Airplane, BuNo 143749

FREQUENCY DISTRIBUTION OF AIRPLANE
OFF-CENTER DISTANCE AT TOUCHDOWN

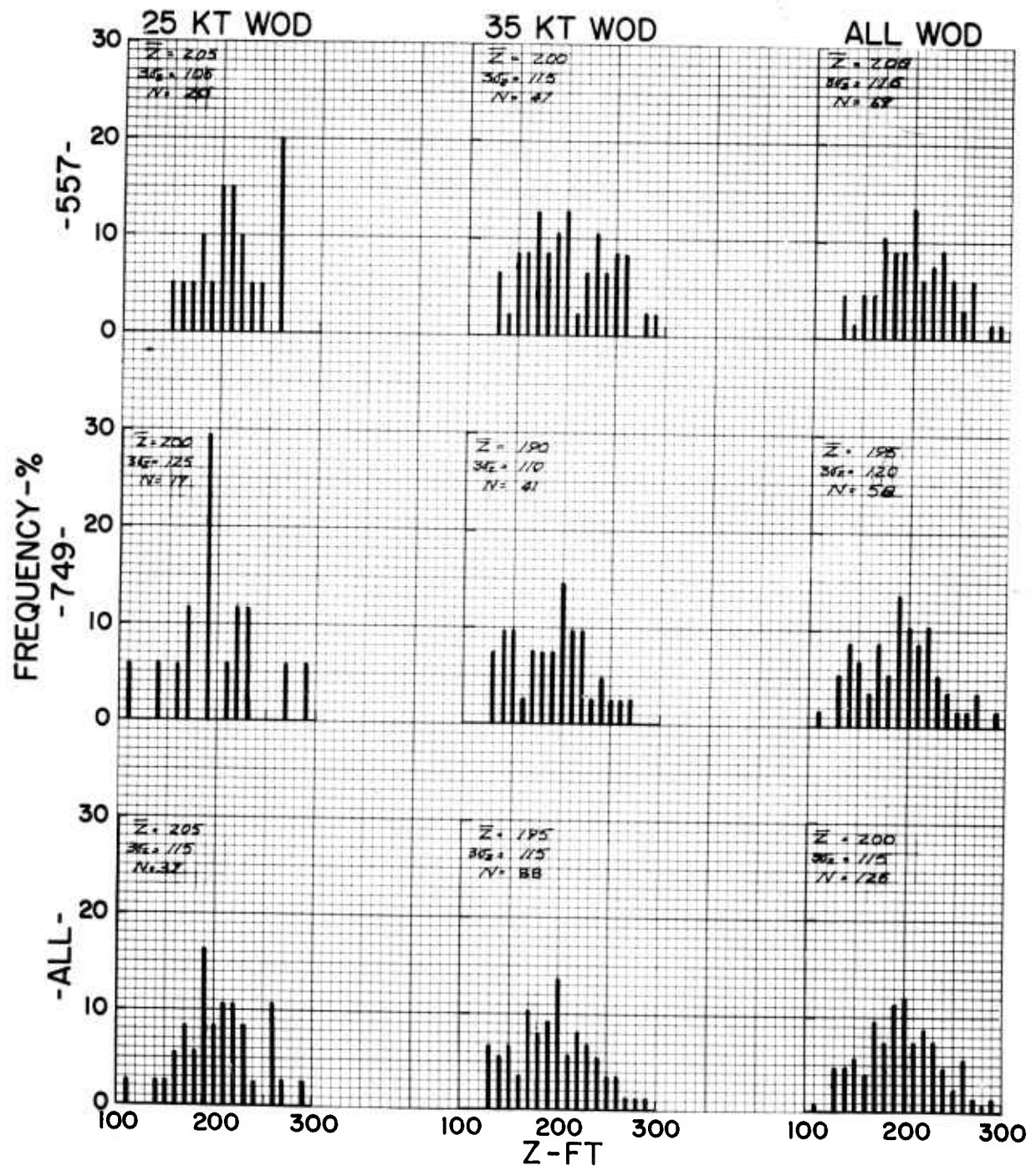


LEGEND: + Starboard
- Port

RA1200001
(RSSH-31003)
FT2222-176

Model F8U-2 Airplane, BuNo 145557
Model F8U-1 Airplane, BuNo 143749

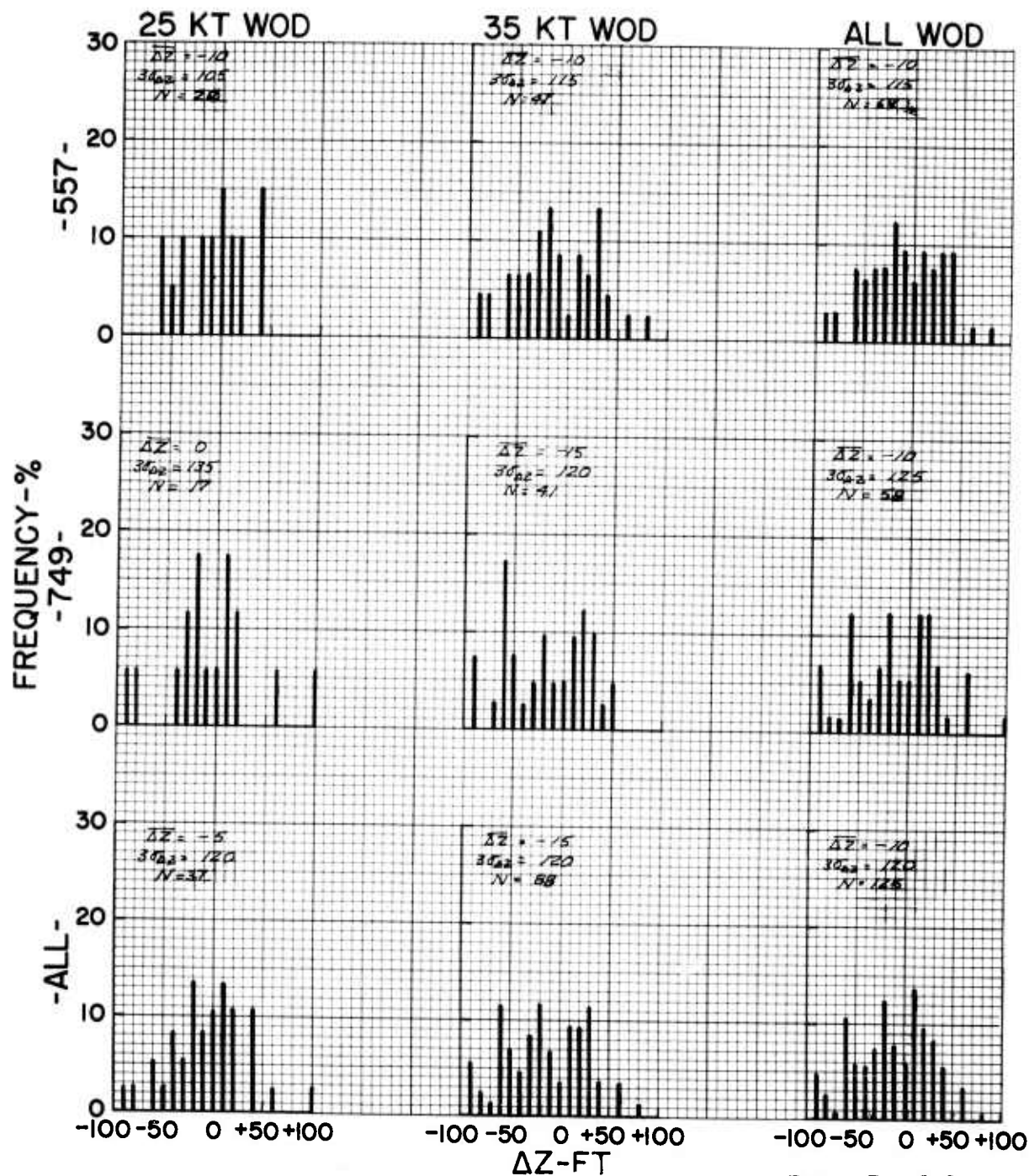
FREQUENCY DISTRIBUTION OF AIRPLANE
MAIN GEAR TOUCHDOWN DISTANCE FROM RAMP



RA1200001
(RSSH-31003)
FT2222-176

Model F8U-2 Airplane, BuNo 145557
Model F8U-1 Airplane, BuNo 143749

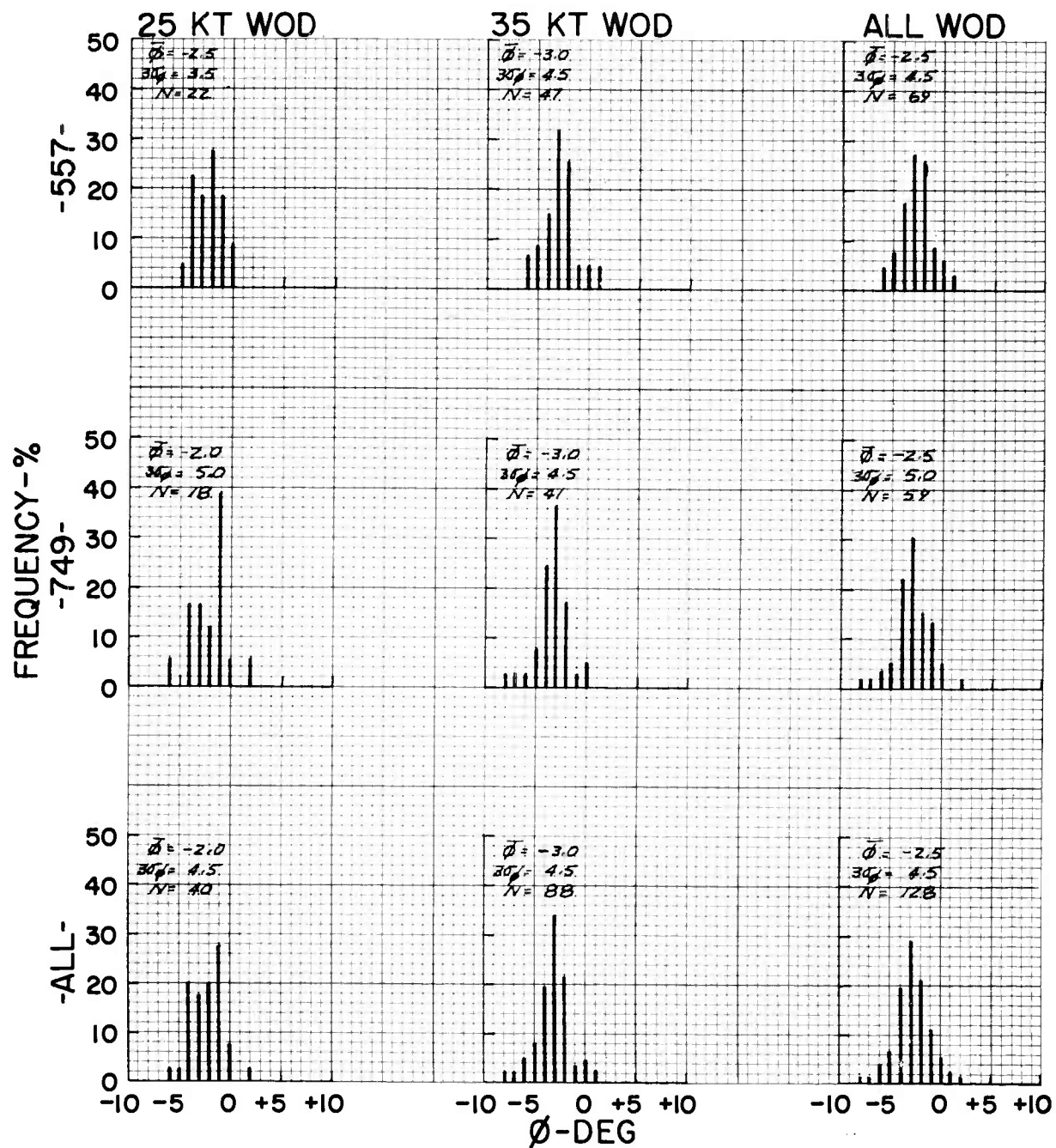
FREQUENCY DISTRIBUTION OF DEVIATION FROM
THEORETICAL MAIN GEAR TOUCHDOWN DISTANCE FROM RAMP



RA1200001
(RSSH-31003)
FT2222- 176

Model F8U-2 Airplane, BuNo 145557
Model F8U-1 Airplane, BuNo 143749

FREQUENCY DISTRIBUTION OF AIRPLANE ROLL ANGLE

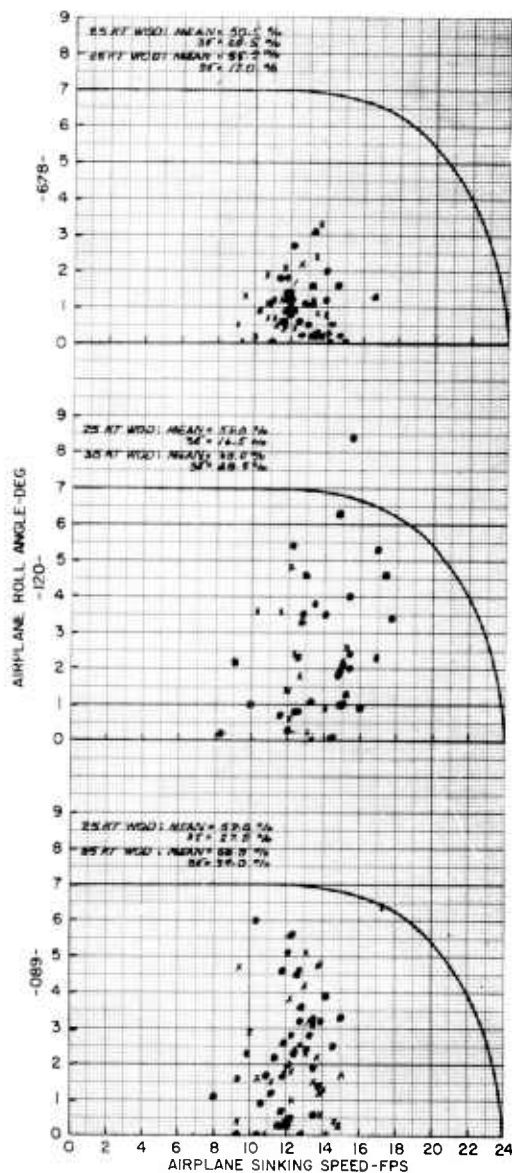


LEGEND: + Starboard
- Port

RA1200001
(RSSH-31003)
FT2222- 176

Model A4D-2 Airplane
BuNo 142678
BuNo 142120
BuNo 142089

COMPARISON OF PER CENT ULTIMATE
SINKING SPEED/ROLL ANGLE ENVELOPE



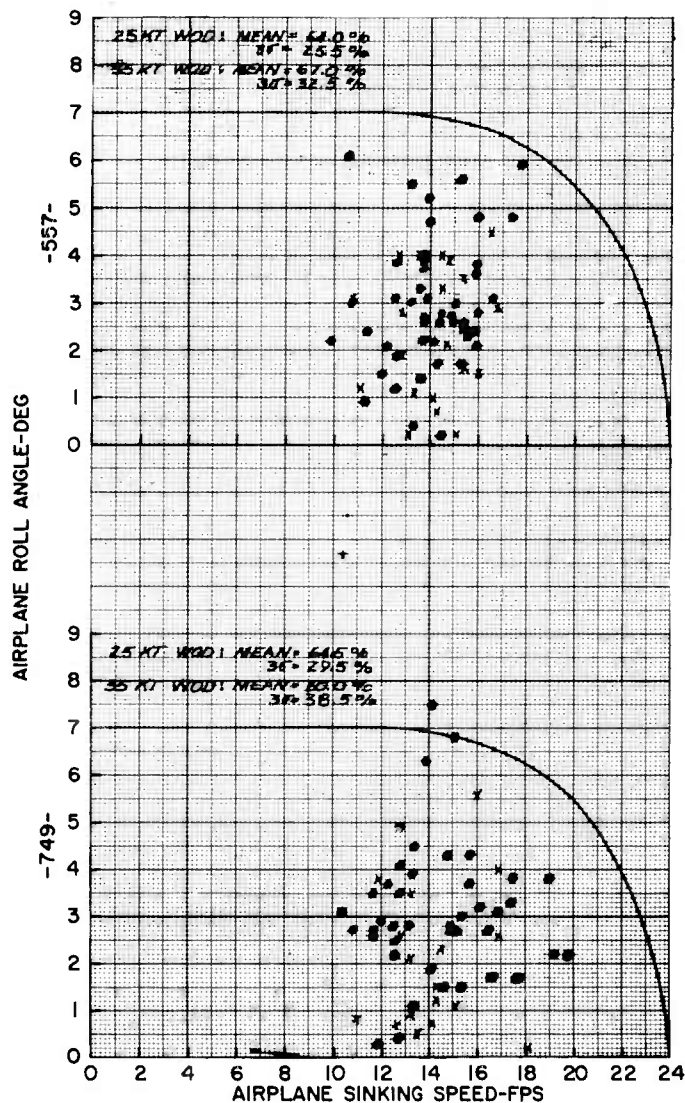
LEGEND: X - 25 kt WOD
● - 35 kt WOD

RA1200001
(RSSH-31003)
FT2222-176

Model F8U-2 Airplane, BuNo 145557

Model F8U-1 Airplane, BuNo 143749

COMPARISON OF PER CENT ULTIMATE
SINKING SPEED/ROLL ANGLE ENVELOPE



LEGEND: X - 25 kt WOD
● - 35 kt WOD

RA1200001
(RSSH-31003)
FT2222-176

DETERMINATION OF EQUATIONS UTILIZED IN THE
STATISTICAL ANALYSIS OF AIRPLANE LANDING PARAMETERS

MK VI, MOD 0 FLOLS GLIDE SLOPE

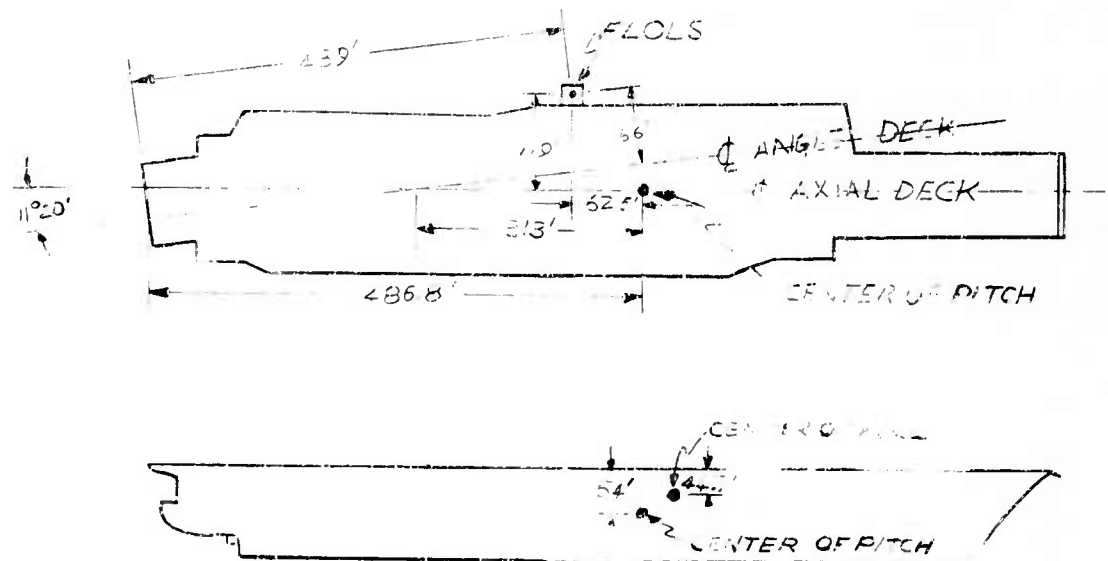


Figure 1

Figure 1 was extracted from NAEF Drawing No 318325 which shows the location of the FLOLS aboard CVA-43 with respect to the flight deck and the pitch and roll axes. The stabilization system will stabilize the glide slope at a point 2500 ft aft of the unit as a result of pitch and roll signals which it receives from the ship's stable elements.

Assuming a stern pitch down:

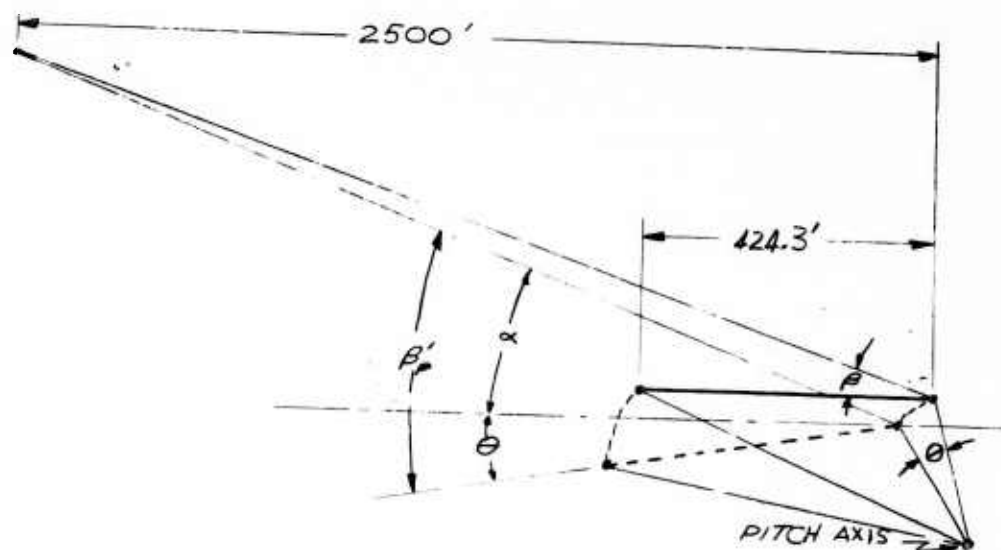


Figure 2

Where, β = OLS glide slope setting, deg

β_p = glide slope angle with respect to the axial deck resulting from pitch, deg

θ = ship's pitch angle with respect to the axial deck, deg

α = angle between the new glide slope angle and the horizontal, deg

Figure 2 is a side view of the carrier perpendicular to the centerline of the axial deck. It is assumed that the vertical and horizontal translation of the FLOLS resulting from pitch are insignificant when compared to 2500 ft which is utilized in computing α .

$$\therefore \beta = \alpha$$

It is also assumed in Figure 2 that the angle between the

axial deck centerline and the horizontal (θ) is equal to the angle between the angle deck centerline and the horizontal which is nearly correct for small values of θ . Therefore, θ is equal to the new glide slope angle with respect to the angle deck centerline.

$$\beta'_p = \beta \pm \theta \quad ; \text{ where, } \theta \text{ is positive for a stern pitch down and negative for a stern pitch up.} \quad (1)$$

The preceding assumptions will result in approximately 0.03-0.05 deg error in determining the value of θ . The new glide slope angle resulting from ship's roll, β'_p , with respect to the angle deck centerline takes into consideration the vertical displacement of the FLOLS and the fact that the centerline of the angle deck does not coincide with the axis of roll. The stern to bow view for a port roll is as follows:

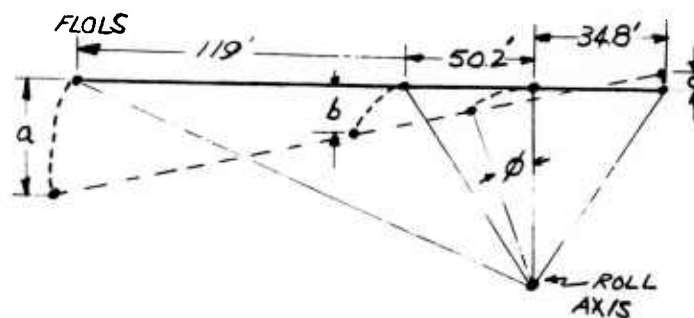
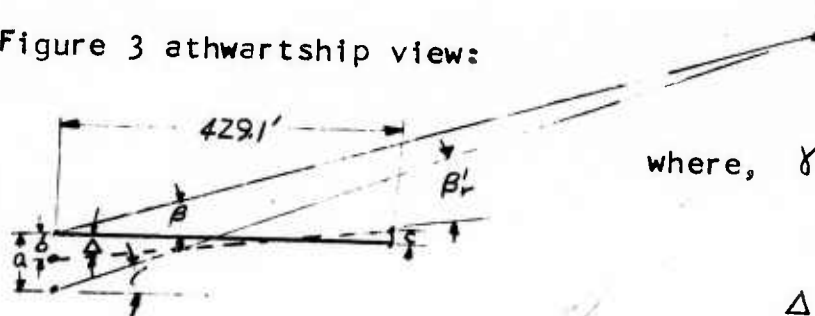


Figure 3

- a = vertical displacement of the FLOLS, ft
- b = vertical displacement of the angle deck centerline opposite the FLOLS, ft
- c = vertical displacement of the angle deck centerline at the ramp, ft
- θ = ship's roll angle, deg

Figure 3 athwartship view:



where, γ = angle between
new glide slope
and horizontal,
deg

Δ = angle between
horizontal and
angle deck
centerline, deg

β_r = glide slope angle
with respect to
centerline of
angle deck re-
sulting from
roll, deg.

Figure 4

From Figure 4:

$$\gamma = \beta + \tan^{-1}\left(\frac{a}{2500}\right) \quad (2)$$

$$\Delta = \sin^{-1}\left(\frac{b+c}{429.1}\right) \quad (3)$$

$$\beta_r = \beta + \tan^{-1}\left(\frac{a}{2500}\right) - \sin^{-1}\left(\frac{b+c}{429.1}\right) \quad (4)$$

Determining the values of a, b and c for small values* of ϕ and substituting in equation (4), the approximate value of β_r is as follows:

$$\beta_r = \beta \mp \frac{\phi}{7} \quad ; \text{ where, } \phi \text{ is positive for a starboard roll and negative for a port roll.} \quad (5)$$

The error in equation (5) is approximately 0.008 deg. To determine the glide slope angle with respect to the angle deck centerline resulting from a combination of pitch and roll, β_r ,

equations (1) and (5) were combined as follows:

$$\beta' = \beta \pm \theta \neq \frac{\phi}{7} \quad (6)$$

THEORETICAL MAIN GEAR TOUCHDOWN DISTANCE FROM THE RAMP (MGTD_T)

The theoretical main gear touchdown distance from the ramp (MGTD_T) was determined by first taking into consideration the variation in the optical touchdown distance (OPTD) as a function of the ship's pitch and roll and the eye to ramp (E/R) clearance in the following manner:

$$\text{OPTD} = \frac{E/R}{\tan \beta'} \quad (7)$$

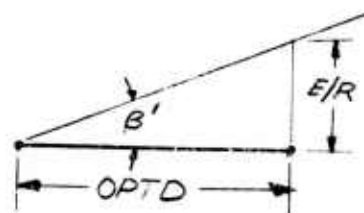


Figure 5

Where, β' is the resultant glide slope determined from equation (6).

The E/R for a steady deck is a function of the OLS glide slope angle and FLOLS lateral roll angle which was adjusted according to Aircraft Recovery Bulletin 10A. The FLOLS roll angle dial setting is $6\frac{1}{2}^\circ$ when there is no lateral roll angle in the FLOLS and it was assumed when this condition existed and the deck was steady (0° ship's pitch and roll) the OPTD is 439 ft forward of the ramp or the location of the FLOLS. Thus, equation (7) was expanded as follows:

$$\text{OPTD} = \frac{E/R \pm d}{\tan \beta'} = \frac{439 \tan \beta' \pm d}{\tan \beta'} = 439 \pm \frac{d}{\tan \beta'} \quad (8)$$

Where, d is the vertical displacement of the glide slope at the centerline of the angle deck which results from adjusting the FLOLS roll angle with the type of airplane. From the FLOLS roll angle settings and Figure 1, the value of d is as follows:

RA1200001
(RSSH-31003)
FT2222- 176

Glide Slope Angle, deg	$3\frac{1}{2}$		4	
Airplane Type	F8U	A4D	F8U	A4D
FLOLS Roll Angle, deg	$4\frac{3}{4}$	$6\frac{3}{4}$	3	$4\frac{3}{4}$
d, ft	-2.0	-0.3	-4.0	-2.0
Predicted Hook to Ramp Distance, ft	11.1	11.3	12.9	12.8

The previous assumption that the centerline of the FLOLS is the OPTD for a steady deck is not correct because of the athwartship camber of the flight deck. According to Aircraft Recovery Bulletin 10-2 the camber at the installation of the FLOLS is 6 in, and the horizontal datum bars are $3\frac{1}{2}$ in, below the flight deck. This error is present in the statistical analysis of the MGTDT and will vary from 10-15 ft depending upon the OLS glide slope setting and the pitch and roll of the ship.

Equation (8) is then combined with the geometry of the airplane and the actual airplane pitch attitude (ϵ) at touchdown.

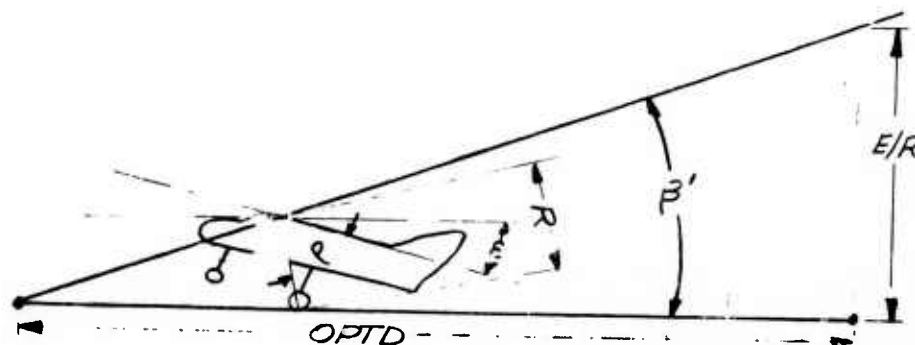


Figure 6

RA1200001
(RSSH-31003)
FT2222-176

In figure 6 the variables are ϵ and β' ; R and ρ are constant depending on the airplane type. Combining equation (8) and Figure 6, the following equation is the $MGTD_T$:

$$MGTD_T = 439 \pm \frac{d}{\tan \epsilon'} - R \left[\frac{\cos(90 - \rho - \epsilon)}{\tan \beta'} + \sin(90 - \rho - \epsilon) \right] \quad (9)$$

The values of R and ρ are as follows:

Airplane Type	F8U	A4D
R , ft	30.0	16.7
ρ , deg	22.1	39.5

The angle ϵ was determined from camera coverage of the landing area and β' from the ship's pitch and roll.

BOLTER RATE FOR TOUCH AND GO LANDINGS (BR)

The Bolter Rate for touch and go landings (BR) was found by determining from the airplane geometry the $MGTD$ required for the arresting hook to land 235 ft forward of the ramp (last cross deck pendant). Since the pitch and roll of the ship was negligible, a constant glide slope angle was assumed. Since the $MGTD$ does not vary appreciably with the airplane pitch attitude, it was also assumed constant.

Airplane Type	F8U		A4D	
β' , deg	$3\frac{1}{2}$	4	$3\frac{1}{2}$	4
ϵ , deg	4	4	9	9
$MGTD_{hook\ 235}$, ft	251	250.5	263	260.5

RA1200001
(RSSH-31003)
FT2222-176

BR was determined from the standard deviation (σ) and the average MGTD (MGTD) as follows:

$$BR = \frac{MGTD_{h00K235} - \overline{MGTD}}{\sigma_{MGTD}} \quad (10)$$

THEORETICAL AIRPLANE SINKING SPEED (V_{St})

The theoretical airplane sinking speed (V_{St}) was determined from the glide slope angle calculated by equation (7) and the airplane engaging speed as follows:

$$V_{St} = V_E (1.69) \tan \beta' \quad (11)$$

PERCENT OF ULTIMATE SINKING SPEED/ROLL ANGLE ENVELOPE ($\%V_s/\phi$)

MIL-A-8629 (Aer) specifies that with 7° of airplane roll with respect to the landing surface, the airplane must be designed to withstand 50% of the ultimate sinking speed and that the relationship between roll angle and sinking speed for design purposes is to be as follows:

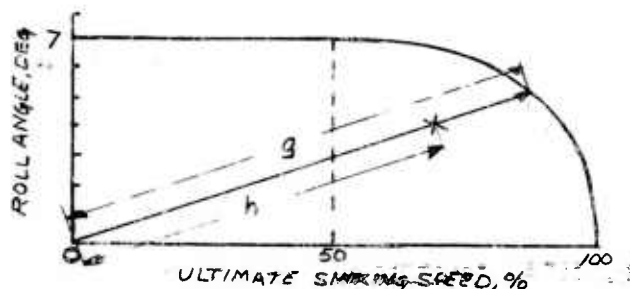


Figure 7

The combination of V_s/ϕ for each landing was plotted on Figure 7 and the $\%V_s/\phi$ was determined as follows utilizing 0° roll angle and 0 fps sinking speed as the common point:

$$\%V_s/\phi = \frac{h}{g} \quad (12)$$

RA1200001
(RSSH-31003)
FT2222- 176

ABBREVIATIONS AND SYMBOLS

T&G - Touch and go landing

B - Bolter

A - Arrested Landing

V_A - Approach Speed, kt

ΔV_A - Actual approach speed minus recommended approach speed from applicable flight handbooks, kt

V_S - Sinking speed (average of Mitchell Camera and Cameraflex Readings) fps

ΔV_S - Actual sinking speed minus theoretical sinking speed, fps

MG/R - Main gear to ramp clearance, ft

X - Off-center distance at touchdown, ft

Y - Off-center distance at the ramp, ft

Z - Main gear touchdown distance from ramp (Cameraflex when Mitchell Camera data are not available), ft

ΔZ - Actual main gear touchdown distance minus theoretical main gear touchdown, ft

ϕ - Airplane roll angle with respect to angle deck, deg

Θ - Pitch attitude with respect to the horizontal, deg

N - Number of landings

σ - Standard deviation

> - Greater than
< - Less than (Used on enclosures (7) and (8) to designate the % landings outside the limits of the curve)

NOTE: A bar over symbol designates the mean.

Enclosure (11)

BIBLIOGRAPHY OF SELECTED REPORTS
PERTINENT TO "BURBLE" AND WOD VARIATION

1. WIND DIRECTION AND SPEED ACROSS THE FLIGHT DECK OF USS RANGER (CVA 61) (CVA 59 class) (Unclas) by T. K. Kjellman and R. B. Colt. Survey rept Apr 58 by Friez Instrument Div., Bendix Aviation Corp., Baltimore Md. (ASTIA file ref No. AD-162 463 Div. 31,2).

Purpose: Tests at conditions representative of aircraft operations were run aboard USS RANGER to determine how the relative wind direction and velocity differs at various locations on the ship with respect to the yardarm wind detectors.

2. WIND DIRECTION AND SPEED ACROSS THE FLIGHT DECK OF THE USS TICONDEROGA (CVA 14) (CVA 19 Angled Deck Class) (Unclas) by T. K. Kjellman and R. B. Colt. Survey rept Aug 57 by Friez Instrument Div., Bendix Aviation Corp., Baltimore, Md. (ASTIA file ref No. AD-162 465 Div. 31,2).

Purpose: Same as paragraph 1.

3. WIND DIRECTION AND SPEED ACROSS THE FLIGHT DECK OF THE USS VALLEY FORGE (CVS 45) (CVS 9 (Ex CVA 9) Class) (Unclas) by T. K. Kjellman and R. B. Colt. Survey rept Feb 58 by Friez Instrument Div., Bendix Aviation Corp., Baltimore, Md. (ASTIA file ref No. AD-162 464 Div. 2,31).

Purpose: Same as paragraphs 1 and 2.

4. WIND SURVEY OF CVA TYPE CARRIER (Unclas) by T. K. Kjellman. Final Engineering rept on Phase I for Jun 56 - May 58 by Friez Instrument Div., Bendix Aviation Corp., Baltimore, Md. (ASTIA file ref No. AD-162 621 Div. 2,31).

Purpose: Test conditions were chosen to represent winds significant for aircraft operations and true meteorological computations using wind direction and speed across the flight decks of the USS RANGER, USS TICONDEROGA and USS VALLEY FORGE.

5. CARRIER CROSSWIND LAUNCHING AND LANDING OPERATIONS WITH CURRENT NAVY AIRPLANES (Conf), special rept 3 Jan 58. Naval Air Test Center, Patuxent River, Md. Proj. TED No. PTR SI 4291 ser No. FT35-04. (ASTIA file ref No. AD-153 660 Div. 1/2).

RA1200001
(RSSH-31003)
FT2222-176

Purpose: (Confidential report).

6. CARRIER CROSSWIND LAUNCHING AND LANDING OPERATIONS WITH CURRENT NAVY AIRPLANES (Conf), rept No. 1, 19 Aug 58 by J. J. Olenski and T. P. Dankworth. Naval Air Test Center, Patuxent River, Md. Proj. TED No. PTR SI-4291 ser No. FT35-093. (ASTIA file ref No. AD-307 340L Div. 1/4).

Purpose: (Confidential report).

7. CARRIER CROSSWIND LAUNCHING AND LANDING OPERATIONS WITH CURRENT NAVY AIRPLANES (Conf), rept No. 2 (final) 18 Nov 58 by K. deBooy and T. P. Dankworth. Naval Air Test Center, Patuxent River, Md. Proj. TED No. PTR SI-4291 ser No. FT35-0137. (ASTIA file ref No. AD-305 621L Div. 1/4).

Purpose: (Confidential report).

8. A COMPARISON OF AIRFLOW WITH AND WITHOUT CONSIDERATION FOR ANGULARITY EFFECTS IN THE WAKE OF A CVA-(N)65 AIRCRAFT CARRIER MODEL (Conf) by W. F. Barnett and M. P. Schultz 23 May 60 David Taylor Model Basin Aerodynamics Laboratory Aero. Test A-479.

Purpose: (Confidential report).

9. CARRIER AIRFLOW ANALYSIS CVA 66 GLIDE PATH STUDIES (Unclas) by C. S. Hoover 28 Sep 61. Naval Air Engineering Laboratory (Ship Installations) ENG-6829.

Purpose: The results of a study conducted in the Naval Air Engineering Laboratory (Ship Installations) three-dimensional wind tunnel to investigate the airflow in the wake of the CVA 66, particularly in the glide path of a landing aircraft. Causes of undesirable effects as well as possible corrections are included in the study.

10. NOTE ON THE AIRFLOW OVER AN AIRCRAFT CARRIER (Unclas) by F. O. Ringleb. Naval Air Engineering Laboratory (Ship Installations) SE-05:FOR:mf, undated.

Purpose: Observations and experiments carried out in the three-dimensional smoke tunnel at the Naval Air Engineering Laboratory (Ship Installations) to determine principal factors influencing the airflow astern of the aircraft carrier.